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CLEVELAND—THE CONVENTION CITY

HUMMING with industrial activity; teeming with business enterprise and progressiveness; mindful always of maintaining its proud record of civic accomplishment; ever careful of the

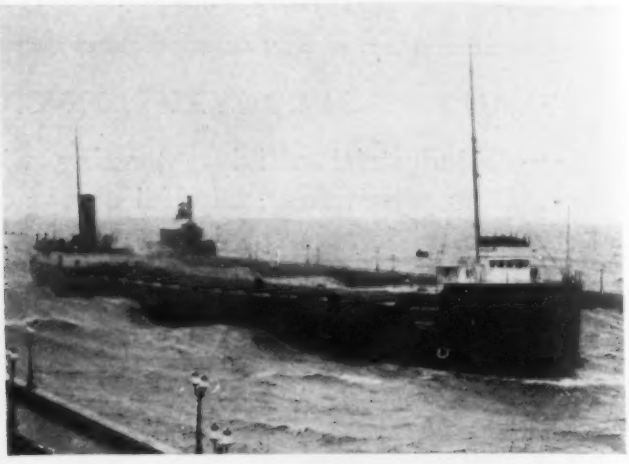
The Cleveland Public Auditorium where the Seventh Annual Convention and National Steel Exposition will be held September 14 to 18, 1925.

health, comfort and recreation of its people and every inhabitant a booster of his city—this is Cleveland.

Probably no city in the United States today outranks Cleveland in the stability of its growth. Approximately one million people live in Cleveland and in its many suburban residential

districts. Cleveland proper is the fifth city in the country in population and second to none in the possibilities for future growth and expansion.

This is made possible by Cleveland's exceptional geographical location and the resultant commercial advantages. The city's position on the shores of Lake Erie midway between rich ore deposits



An Iron Ore Freighter Entering Cleveland Harbor.

of the Lake Superior region and the vast coal fields of Ohio, Pennsylvania and West Virginia, and close to the extensive limestone quarries of Ohio, make it one of the largest iron and steel centers of the country and this industry forms its leading activity.

Cleveland has convenient transportation facilities by rail and water and is situated where raw materials may be collected easily and at a low cost. It is the center of a wonderful market of unlimited production and buying power. Its thirty-five hundred manufacturing plants have an annual output exceeding $1,091,000,000 in products.

Cleveland's manufacturing is remarkably diversified, including the production of iron and steel; aluminum, iron, steel and brass castings, bolts and nuts; wire springs, wire fence and wire nails; tools and machine tools; hoisting and conveying machinery, screws and tacks; railroad suplies; stoves for oil, gas and coal; hardware; sewing machines; office furniture and multigraphs; scientific instruments; chemicals; paints and varnishes; oils and greases; automobiles, electric carbons; batteries and other accessories; steel ships, wire rods, barb wire, piano wires, electric

wires, cable and wire ropes are produced in great quantities; while plates, sheets and miscellaneous products go to make up the balance of the big total.

Cleveland practically leads the country in the production of wire, nails, bolts and screws, malleable castings and heavy machinery. It has a high rank as a producer of tacks, drills, steam hammers, lathes, punches, shears, forges and automatic screw machines.

The High Level Bridge Spans the Cuyahoga River and Valley and is the Principal Artery of Travel between the East and West Sections of the City. It is the Largest Double-deck, Reinforced Concrete Bridge in the world. Its Center Span is 591 feet long and 95 feet above the Lake Level and is Built of Nickel Steel. It has a Total Length of 2,880 feet and is 81½ feet wide. It was Constructed at a cost of $5,407,000.

Cleveland's part in the automobile industry is not confined to the production of cars. The city leads in the production of automobile parts and accessories. Here more springs are made for automobiles, wagons and carriages than anywhere else, one firm alone normally turning out more than 6,500 springs a day. No other American city is even a close rival in the production of storage batteries, motor cylinders, rims and tubing. Cleveland factories have daily production capacities of more than 2,000 automobile cylinders, 15,000 carriage wheel rims, 1,500 bands for truck wheels, and 1,200 bases for truck tires. Frames, axles, bearings, fittings of various sorts, bodies, carburetors, crank shafts, motors, wheels, tubings, forgings, stampings and castings for every make of automobile are produced in large quantities.

Expansion of automobile manufacturing in Cleveland has been

one of the city's most recent developments. Pleasure cars manufactured include the Chandler, Cleveland, Jordan, Peerless, Stearns, Rollin and Baker Electric. White trucks are made in Cleveland. The development of this industry has had no mushroom features but is the result of the recognition by motor car experts of Cleveland's logical advantages.

Cleveland's woolen mills and allied industries represent a capital of between $6,000,000 and $8,000,000. Enough cloth is woven in this city every year to make in the neighborhood of 2,000,000

The Federal Building—Housing the Federal Courts, Customs Offices and Cleveland Post Office.

suits. There are several thousand people and 700 looms in one mill alone, which consumes 15 tons of fleece per day. One blanket mill and more than two dozen knitting mills, representing a combined capital of more than $8,000,000 turn out vast quantities of blankets, sweaters, caps, shawls, scarfs and other knitted articles.

Cleveland is the second city in the country in the production of women's ready-to-wear garments.

For the last twenty years Cleveland has been the first city in the United States in the manufacture of varnish and paint and the two largest paint companies in the world are located here. The output of refined oil totals 1,000,000,000 gallons annually.

A number of miscellaneous products aid in the importance and development of Cleveland. It is one of the largest hardware producing centers in the United States. There are several large manufacturers of steel office furniture, printing presses and paper cutters. The only multigraph manufacturing concern in the country is lo-

cated in Cleveland. Only one city in the United States produces more sewing machines than this industrial center. Plumbing supplies, railroad frogs and crossings, kitchen utensils, washing machines, aluminum wares, lamps, lighting fixtures, roofing materials, toilet articles, toys, rubber goods, and small novelties are manufactured in vast quantities.

In 1876, Charles F. Brush, a Cleveland citizen and inventor, gave his first demonstration of his arc lamp in the public square in Cleveland. From Cleveland, too, a mighty influence is exerted upon lighting problems of the world, for here is located the head-

Birdseye View of Piers at the Foot of East Ninth Street Used for Passenger and Freight Service Principally Between Detroit and Buffalo.

quarters of the National Electric Lamp Association. Executive offices and the laboratories of this company occupy a beautiful tract of seventy-five acres, known as Nela Park. It contains buildings for administration, research, engineering and operating. It stands forth pre-eminently as a seat for scientific research work. From the laboratories come reports and testimony at frequent intervals of innovations, improvements and corrections of electric lighting devices.

Cleveland has 14.2 miles of lake frontage, protected by a breakwater 5¾ miles in length, constructed by the Federal Government at a cost of approximately $6,000,000 with an additional $1,000,000 expended in dredging and maintenance. The harbor has a spacious entrance and the extension of East 9th St. has made possible the construction of several passenger piers affording ample dockage for

passenger and freight service from Detroit and Buffalo. These docks are located east of the harbor entrance, while the harbor to the west affords unexcelled facilities for handling and storage of iron ore. The Cuyahoga river, which is navigable for several miles and flows into Lake Erie at Cleveland, is also lined with docks adjacent to which are many furnaces, factories and lumber yards. Many of these docks are equipped with ore handling buckets having

A General View of Ore Unloading Docks and Ore Piles at Cleveland's Harbor.

a "grab" of ten, seventeen and twenty tons of ore. An ordinary ore car may be unloaded by three "grabs" of a single bucket.

In the operation of loading the large lake freighters with coal, the railway cars are lashed to a platform or hoist which is raised and then the car and platform tipped and its contents dumped bodily into a hopper or funnel which leads to the hatches of the steamer.

The largest Lake freight carriers are over 600 feet long and have capacities up to 12,000 tons. More than 800 ships ply the Great Lakes during the seven or eight months the ports are open. In the coal, ore and grain trade, about 450 bulk freight ships are employed, of which approximately 80 per cent are owned or managed by Cleveland firms.

At a special city election the erection of a new Union passenger terminal by the Cleveland Union Terminals Company was authorized. This station, the estimated cost of which is $50,000,000, is planned to occupy the property fronting on the Public Square. This project is now well under construction.

Cleveland is bountifully supplied with modern, splendidly

equipped and centrally located hotels, in which good rooms always may be obtained at moderate rates.

Cleveland is fast becoming one of the most popular convention cities in America.

Its geographical location, which permits the majority of the in-

Monument of General Moses Cleaveland, Founder of the City of Cleveland, located in the Public Square.

habitants of the country to reach it over night, makes it an ideal convention center. Through over-night trains, with finest Pullman standard sleeping cars, are operated daily into Cleveland from Detroit, Chicago, St. Louis, Cincinnati, Pittsburgh, Washington, Baltimore, Philadelphia, New York, Boston, Buffalo, Toronto, and many intermediate points, while through sleeping car service is also available during winter months from Atlanta, Birmingham, Chattanooga and Jacksonville.

The original mold in which Cleveland was cast was of the New England pattern. The lands in the northeastern corner of Ohio had been granted by the United States Government to Connecticut,

after the Revolution, in the settlement of claims made by the seaboard states to western territory, under old colonial grants. The state sold the larger part of its possessions in Ohio to a group of Connecticut men known as the Connecticut Land Company. In 1796 that corporation sent a party of surveyors headed by General Moses Cleaveland to lay out a town site at the mouth of the Cuyahoga River.

Cleveland more than doubled its population during several of the government's ten-year census periods and multiplied it by five

A View in Gordon Park.

in forty years, because of the location of the city affording remarkable facilities for the manufacture of iron and steel and their products, and for the transportation of heavy freight by water, at the lowest possible cost, and because Cleveland is the natural business center of a rich and favored region.

Parks and boulevards extend in a great chain around the larger part of the city, lacking only a few connecting links to make a complete girdle of green in summer. Gordon Park and Edgewater Park, the latter on the West Side, as the great section west of the Cuyahoga River is called, reserve for the people forever two miles on the Lake front and provide bathing beaches, boating facilities and playgrounds swept by cool breezes in summer. There are nine parks with from 85 acres to nearly 300 each, and the park system includes numerous smaller parks and many miles of boulevards.

(More about Cleveland in the next issue.)

SPRING SECTIONAL MEETING

THE Spring Meeting to be held in Schenectady, May 28, 29 and 30, 1925, gives every indication of being one of the most successful and best attended sectional meetings held by the Society. A number of interesting plant inspection trips have been arranged, alternating with technical sessions and the entire program will prove interesting and instructive.

The Papers Committee has prepared a list of high grade technical papers.

The new Hotel Van Curler will be open and members planning to attend this meeting are requested to send in their reservations to the manager of the hotel.

The tentative program is as follows:

THURSDAY, MAY 28

Registration—9:30 to 10:30 A. M. at Hotel Van Curler.

Technical session—10:30 to 12:00 M. at Hotel Van Curler.

Leave by auto for Watervliet for lunch and inspection of Ludlum Steel Company's plant.

Banquet—6:30 P. M. at Hotel Van Curler.

Address of Welcome—William Dalton, president of the Schenectady Chamber of Commerce.

Response—W. S. Bidle, president, A. S. S. T.

Address—Dr. W. R. Whitney, Director, Research Laboratory of General Electric Company.

Address— R. B. McColl, manager, American Locomotive Works.

Paper—"Results of Examination of Metals with the X-ray." Colonel Tracy C. Dickson, commanding officer, Watertown Arsenal.

Paper—"Manufacture of Guns by the Cold Working Process." Dr. F. C. Langenberg, director of Laboratories, Watertown Arsenal.

FRIDAY, MAY 29

Meeting at Hotel Van Curler at 9:00 A. M.

Inspection of plant of American Locomotive Works until 11:30 A. M. Those who do not desire to visit the American Locomotive Works may begin inspection of the plant of the General Electric Company. Both groups will meet at the General Electric Company for lunch at 1:30 P. M.

Address of Welcome—C. C. Eveleth, manager, General Electric Company.

Technical session—4:30 P. M. in the assembly room of the General Electric Company's research Laboratory.

Technical session—7:30 P. M. at Hotel Van Curler.

SATURDAY, MAY 30

Leave promptly at 8:30 A. M. for trip to Lake George. Return about 6:00 P. M.

LAKE GEORGE AUTOMOBILE TRIP.

For the benefit of all visiting members, their wives and families an automobile trip to Lake George is planned for Saturday, May 30th. This is one of the most delightful trips that could be arranged. The lake lies fifty miles north of Schenectady and is well within the rugged Adirondacks. It is one of the beauty-spots of the world. Nestled in the wooded mountains it lies, a beautiful sheet of water thirty miles long, dotted with islands, surrounded by water of crystal clearness, in the shallows and in its depth a tint of blue matched only by the summer skies. Along its shores are summer homes, some simple rustic camps, and others, palaces of stone with gardens and drives surrounding them in luxurious spaciousness.

The road leads north out of Schenectady through a pretty, rolling farm country, several rural villages, through the town of Ballston Spa, to Saratoga. Here are the famous springs visited by thousands each season. Mineral waters of all kinds flow freely from nature's underground laboratories. Some are so highly carbonated, the water is shot geyser-like many feet into the air. Here is the famous race-track and the two old hotels "The United States" and "The Grand Union" of Civil War memory and a summer resort

of southern planters and horsemen in the days "befo the wah." A few miles beyond the track is Saratoga Lake, a body of water well worth seeing, seven miles long. On the road to the lake is the "Trask Estate" where Edgar Allen Poe used to visit and was inspired to write his immortal "Raven."

A few miles farther east are seen the Green Mountains of Vermont and the site of the Battle of Saratoga, one of the decisive battles of the Revolution, where Burgoyne surrendered. This whole region is rich in Colonial and Revolutionary associations.

Going north again from Saratoga, we soon see the hills that mark the beginning of the Adirondacks. Mt. MacGregor is on the left, where the Metropolitan Insurance Company has a sanitarium on the summit and where is located the house in which General Grant died. A few miles farther on we cross the Hudson and are in Glens Falls, the charming metropolis of the North Country. The falls on the river can be visited and in the rocks at the base is the cave which Cooper described in "The Last of the Mohicans."

Beyond Glens Falls we follow a winding road a few miles and then begin descending, with rocky walls on one side and a deep gorge on the other. Suddenly at the right through a gap in the hills is seen Lake George, the loveliest scene east of the Rocky Mountains, and, in the opinion of many European visitors, equal in beauty to the Alpine lakes.

We drive through the village and for six miles along the lake to Bolton. On the return trip, we make a sharp right turn in the village and run through a wilder and more beautiful section of the Adirondacks. On the way we pass Lake Luzerne and run along the upper Hudson where it has emerged from the mountains, crossing the Sacandaga River, a rough, turbulent mountain stream, coming along a torturous course through the hills from far up in the woods where the speckled trout lie hiding in deep shaded pools.

This road continues to Saratoga, where we take up the old trail to Schenectady.

May we urge all the members to make this trip for it should not be missed while you are in the vicinity. Arrangements will be made for lunch on the trip and cars will be provided for all who do not drive their own. The return will be made in time for the night trains to Boston and New York or the West.

Delegates living within automobile driving distance of Schenectady are urged to bring their cars. Schenectady is located within an easy day's touring of much country noted for scenic beauty. Parts of the Adirondacks, the Green Mountains of Vermont and the Berkshires of Massachusetts can be visited and return made the same day on excellent roads. It will repay those who like touring through mountainous country to stay over Saturday and Sunday, and longer, if possible.

A NEW SERVICE

ATTENTION of the membership of the Society is called to pages 38, 74 and 75 in the advertising section of this issue of TRANSACTIONS on which are listed books of interest. This list has been carefully selected from practically all of the technical publishers and members may secure them by sending in their orders to headquarters.

Many members already have libraries and find them to be very valuable assistance in their work. Those who do not will undoubtedly find it worth while to begin the accumulation of books on the subject of their chosen profession. This working library that you may wish to secure does not need to be purchased in its entirety at one time, additions should be made from month to month in the same manner in which additions are made to your savings account. It will be surprising in how short a time a valuable accumulation of interesting books will be obtained. It is suggested you read the list of books and their contents very carefully, select the ones you need and want and send in your request for them at once.

DR. MARION L. BURTON

IT is with sincere regret that we have learned of the death of the University of Michigan's fifth president, Dr. Marion L. Burton. Dr. Burton died the morning of February 18, 1925, after a prolonged illness. He was born at Brooklyn, Iowa, August 30, 1874.

The untimely death of President Burton causes American education to suffer a heavy loss, and especially "Michigan," to whose service he gave his untiring efforts and energy.

SOME FUNDAMENTAL FACTORS FOR OBTAINING SHARP THERMAL CURVES

By C. Benedicks, K. G. Lund and W. H. Dearden

Abstract

The authors of this paper have given the guiding principles for obtaining more sharply defined thermal curves. The salient points to be observed are:

1. The specimen should possess, as far as possible, a spherical form. A pear-shape is to be recommended, as otherwise the heat conduction along the pyrometer exercises too strong an influence. If it is necessary to use a cylindrical specimen, then all edges should be rounded off.

2. The thermo-junction must be located at the center of the sphere; also in the case of specimens of other shapes it must be placed as centrally as possible.

3. The obtaining of perfect contact between thermo-junction and specimen is most important. If this is not possible, and some insulating layer must be used, the junction should be strengthened so as to make a reasonably good contact.

4. To obtain sharp heating curves it is essential to avoid having the heating winding, or whatever is being used, in the neighborhood of the specimen and thermo-junction.

1. Introduction

DURING some experiments which were made for the purpose of obtaining the evidence of a time-discontinuity at the solidification point of a metal, which from theoretical reasons may be expected, some cooling curves were obtained for control purposes which are of interest in other directions.

The point to be decided was the important question of the distance a thermo-junction should be inserted into the melt in order to obtain the arrests corresponding to a melting or transformation point as clearly and correctly as possible.

A paper presented by title before the Boston Convention of the Society, September, 1924. Of the authors, Dr. Carl Benedicks is director of the Metallographical Institute of Stockholm, Sweden, and Messrs. Lund and Dearden are associates.

2. Cooling Curves with the Thermo-Junction in Different Positions

These experiments were carried out as follows:

A thin-walled cylindrical crucible of Jena glass (external diameter about 9 millimeters, and length about 56 millimeters) was filled with commercially pure tin and heated in an electric furnace. The pyrometer consisted of a copper-constantan thermocouple (wire 0.20 millimeters in diameter), surrounded by a hard glass protection tube from 2.5 to 3 millimeters in diameter. Temperature-time curves were registered photographically by means of a Saladin-LeChatelier registration apparatus (Siemens and

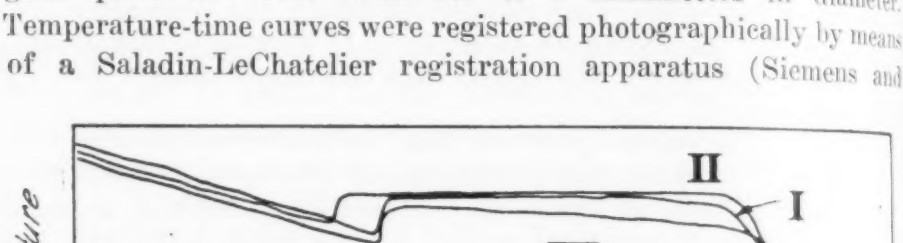


Fig. 1—Time-Temperature Curves of Pure Tin Obtained Photographically. Curve I Obtained with Tip of Pyrometer Nearly at the Bottom of the Crucible. Curve II Obtained with Tip of Pyrometer at Middle of Crucible and Curve III with Tip of Pyrometer Just Below the Surface of the Molten Metal.

Halske). For the curves reproduced here (Fig. 1) the apparatus was so arranged that the ordinates represent temperature and the abscissæ represent time; the coordinate of time was very simply obtained by inserting a second thermocouple in a porcelain block which cooled within, and at the same rate as the furnace itself.

Three strictly comparable cooling curves were registered on the same plate, the tin in each case being preheated to the same temperature. For curve I the tip of the pyrometer tube was pushed down nearly to the bottom of the crucible, for curve II it was raised to the middle of the molten metal, while for curve III it was only about 10 millimeters below the upper surface.

The following remarks apply to the results. It is clear that in curve III the part of the line corresponding to solidification is lower than in the case of the other two curves, and it also shows the temperature to be gradually falling during the whole of this

period. It is evident that the cause of this undesirable result is that the pyrometer tube was not inserted far enough. Accordingly, the gradual decrease of the (apparent) solidification temperature is due to too great a heat conduction along the pyrometer tube.

In curve I a considerable portion of the curve is exactly horizontal, corresponding to solidification—after a certain amount of undercooling—taking place at a constant temperature.

It is evident that in curve II, the important part of the curve, the solidification arrest, is much longer, and in fact this curve is decidedly the best of the three. This gives evidence that the sharpest definition of the freezing point will be obtained when the temperature measurement is made exactly at the center (of gravity) of the mass.

This result—although it might perhaps have been predicted—shows that it is by no means correct when, as is generally the case, the pyrometer is pushed nearly to the bottom of the crucible for the purpose of reducing the loss of heat by conduction. Though, of course, any attempt to ensure such reduction, is in itself justifiable. This risk of loss of heat by conduction while being borne in mind should not be exaggerated. Its only effect is that, as already mentioned, the solidification arrest receives a certain inclination to the horizontal; but, the point of intersection of this straight line with the initial part of the curve must obviously be unaffected by this heat loss and so still give the true freezing point. As a matter of fact, even curve III, in itself unsatisfactory, gives such a point of intersection which very nearly coincides with those of I and II, which do give the correct freezing point.

It can accordingly be concluded here that in a cylindrical mass of metal the pyrometer tube should only be pushed down to the center—or at most only just a little below.

3. Cooling Curves of the Same Mass of Metal in Cylindrical and Spherical Form

The above results emphasize that the temperature measuring point in a cylindrical mass as far as possible should be situated symmetrically. Now if, in general, the measuring point must be situated symmetrically to give the best result, then we can expect that for a given mass of material the best possible result will be

obtained when it possesses a spherical form, and when the temperature measuring point is as nearly as possible at the center.

In order to test this conclusion experimentally, cooling curves of a given amount of metal were obtained, first when it possessed an approximately cylindrical form, and second when it had a nearly spherical form.

The approximately cylindrical mass was simply obtained by means of a thin-walled (2 millimeters) graphite crucible A, Fig. 2,

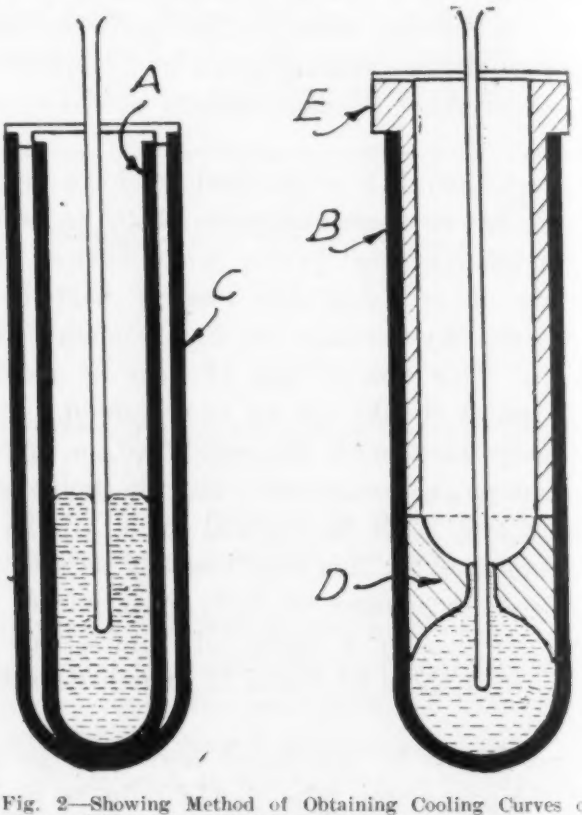


Fig. 2—Showing Method of Obtaining Cooling Curves of the Same Mass of Metal in Cylindrical and Spherical Forms.

of which the internal diameter was 15 millimeters, filled to a height of 39 millimeters with pure lead (about 65 grams).

To obtain a spherical shape the lead was transferred to another graphite crucible B (internal diameter 23 millimeters; length 100 millimeters; wall thickness 2 millimeters). Inside the crucible came a bounding piece D, turned from dried, unburnt porcelain, of which the shape can be seen in Fig. 2. In order to hold this in the right position (against the pressure of the molten lead) a vertical tube E, made from the same material pressed down

upon it. In order to keep the heating conditions as similar as was considered possible, A was placed in another crucible C, identical with B.

The thermocouple (copper-constantan), surrounded by a thin protection tube of "Pyrex" glass, was inserted to a point just below the center of the (approximately) cylindrical mass in A, and exactly to the center in the case of the spherical mass in B. In this latter case the pyrometer displaced some of the molten

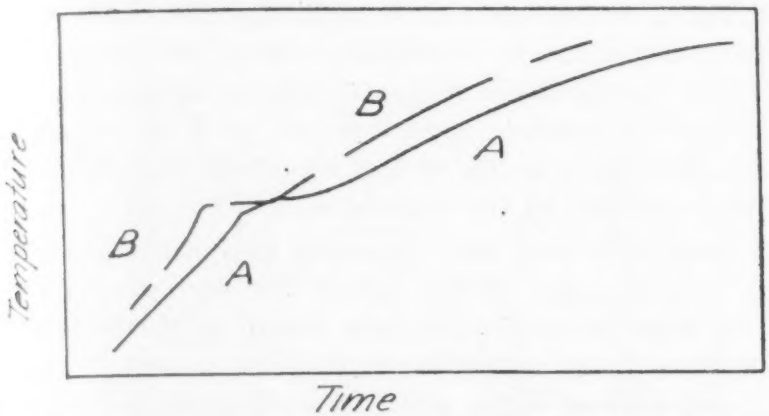


Fig. 3—Time-Temperature Curves of Pure Lead Obtained by the Two Methods Shown in Fig. 2. Curve A is the Cooling Curve of the Cylindrical Mass. Curve B is the Cooling Curve of the Spherical Mass.

metal up into the aperture in D, so that the melt received a pear-shaped form. Thus a rather greater length of the pyrometer was heated by the metal than would correspond to a strictly spherical shape.

The cooling curves were obtained with the same photographic registration apparatus used in the previous experiments. The time coordinate was obtained by inserting a second thermocouple in another crucible which, coming below the one containing the metal, but separated from it by asbestos, cooled at the same rate as the furnace itself. Use was also made of a time indicator which every fifth minute weakened the light for a period of one minute. The preliminary heating, with a current of about 1.06 amperes, was in all cases to the same temperature. The registration was commenced immediately after reducing the current to a smaller amount (0.43 amperes). Curves so obtained are reproduced in Fig. 3. There, the curve A corresponding to the cylindrical mass is left without time indications; the curve B, with time marking, corresponds to the spherical mass. It is clear that in B (sphere)

the cooling process has given, in every way, better results than in A (cylinder). In the curve A it is evidently difficult to say with certainty what is the exact freezing point. The curve B has, on the other hand, nearly an ideal shape. It is specially noteworthy that the change from the solidification horizontal to the subsequent part of the curve produces a sharp angle. In a second photograph, this bend was found nearly as sharp.

Tammann[1] has previously remarked that on all actually observed cooling curves the end of crystallization is not marked by any sharp angle but by a gradual change of direction, on the ground that "a difference begins to appear between the temperature of the thermometric apparatus used and the temperature of the melt, when the quantity of heat conducted away by the former is no longer covered by the heat taken up."[2]

In accordance with this, Tammann gave a method (i. e., production of both parts of the curve) for correcting this rounding off in order to obtain the right length of the horizontal line. But even though this correction be made as accurately as possible, it must obviously be better when no such correction is necessary. Thus the fact now established, namely, that using a nearly spherical mass of metal, sharp angles are obtained in the cooling curve, at the end as well as at the beginning of solidification, is of some importance from the point of view of thermal analysis. It appears to prove that the usual rounding off of the curve in the first place is due to an unequal temperature distribution in the mass of the metal. As a matter of fact, much greater temperature differences must occur in a cylindrical mass than in a spherical one, owing, of course, to the stronger cooling of the peripheral parts. The spherical form evidently must give a temperature distribution as uniform as possible.

There is, however, a characteristic of the B curve in Fig. 3 which needs explanation: the solidification arrest is not strictly horizontal as is theoretically necessary, but exhibits a slight inclination. It can easily be seen that this deviation from the normal course must be due to the heat conduction along the pyrometer—exactly as was shown for curve III, Fig. 1. In order to counteract this source of error, though unimportant, (unimportant because

[1] G. Tammann, Zeitschr. f. anorg. Chemie 47, 289-, 1905.

[2] Loco cit. p. 291.

the temperature estimate of the beginning of solidification is unaffected by it), the upper part of the melt (D, Fig. 2) should be slightly broadened, giving the mass a pear-shaped form.

The foregoing experiments lead to the following conclusions:

To obtain the most correct cooling curves possible the melt should be constrained to a spherical form, and the temperature measured at its center. Of course this neglects heat conduction along the pyrometer; if the latter is taken in consideration, a compromise is to be made between local temperature difference

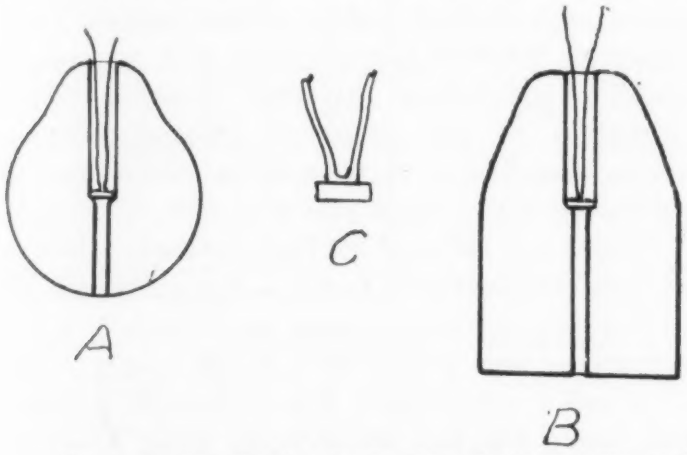


Fig. 4—Sketches Showing the Pear-Shaped (A) and Elongated Cylindrical Pear (B) Specimens of Steel from which Cooling Curves were Obtained. Sketch (C) shows the Manner in which the Platinum-Platinum-Rhodium Thermocouples were Arranged and Inserted in the Specimens.

and heat conduction along the pyrometer. Hence the most rational shape for the melt in this case is that of a nearly spherical pear.

4. Recalescence and Refrigerescence Curves with a Pear-Shaped and an Elongated Specimen, Respectively

It can forthwith be concluded that the above result holds also for heating curves and arrest point determinations in general, such as those of iron and steel. It appeared, however, of interest to make some further controlling experiments.

For critical point determinations two specimens were prepared from the same carbon steel ("silver steel," with 1.17 per cent carbon, 0.30 per cent silicon, and 0.42 per cent manganese. One (A, Fig. 4) was formed in accordance with the previous results, i. e., it was made pear-shaped (diameter 13 millimeters, length 17 millimeters, weight 12 grams). The other specimen

(B) was shaped at the top exactly like A, but was given about 50 per cent greater mass, the lower part being elongated cylindrically—so that it approximated to the commonly employed cylindrical form (diameter 13 millimeters, total height 20 millimeters, weight 17 grams).

Now, according to current ideas, specimen B, on account of its considerably greater mass, should give a more definite arrest point than A. But according to the above observations, A should give the better result—i. e., it should behave thermally purer.

It was at once obvious that to render possible exact comparison the contacts between thermocouple and specimen should be exactly alike in both cases. In order to obtain this result, the welded junctions of two identical platinum-platinum-rhodium thermocouples were formed in the manner shown at C, Fig. 4, i. e., each was provided with a small platinum disc. A platinum globule was first formed on the end of the platinum wire held in the flame, and then the other wire fused to this. The globule was then hammered flat on a perforated steel plate. A hole 1.8 millimeters in diameter having been drilled down to the center of the specimen the thermo-junction was pressed down into it with a small grooved steel punch (using cautious hammering) until it came exactly to the center and was pressed hard against an existing ledge. In order subsequently to be able to release the junction from this extraordinary firm contact a narrower hole (1.0 millimeter) was previously drilled from the lower end up to the center of the specimen. As will be seen in the sequel this method of ensuring perfect contact has been quite satisfactory. Both the thermocouple wires were insulated with thin silica capillaries.

The registrations in this case were carried out with a "Double Thread Recorder," made by the Cambridge Scientific Instrument Co., Ltd. This instrument possesses the considerable advantage that one can obtain the indications of two thermocouples either concurrently with two separate galvanometers, or else alternately by means of one galvanometer registering on the same part of the paper in two different colors—this latter method greatly facilitating the comparison.

The two specimens had, of course, to be heated and cooled together. This was accomplished by placing them symmetrically in a small electrically heated crucible.

An interval of 30 seconds elapsed between successive points of the registered curves. A tracing of one of the records obtained is reproduced in Fig. 5. The upper curve A was given by the pear-shaped specimen, while the more nearly cylindrical one gave the lower curve B.

In the parts of the curves corresponding to cooling it will be observed that in both cases a very clear recalescence point, pre-

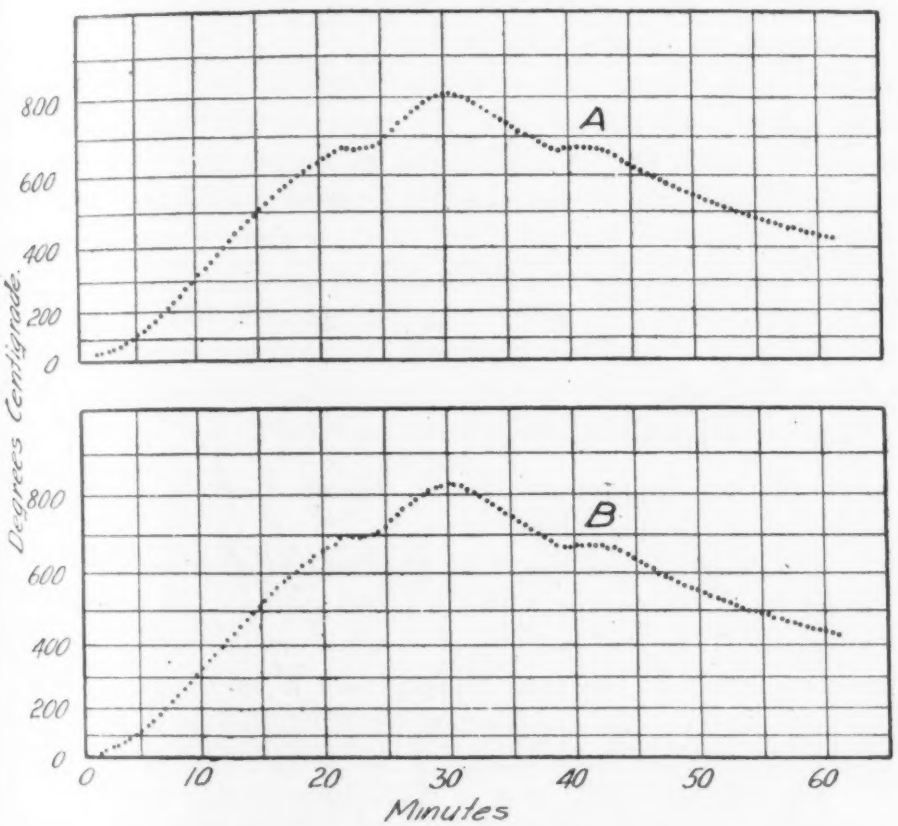


Fig. 5—Heating and Cooling Curves Obtained from Specimens Shown in Fig. 4. The Upper Curve (A) is that of the Pear-Shaped Specimen. The Lower Curve (B) is that of the More Cylindrically-Shaped Specimen.

ceded by some undercooling, appears at about 670 degrees Cent. (1238 degrees Fahr.); there is no definite difference between the two curves.

In the heating curves Ac_1 appears very clearly indeed and it is preceded by a small but marked superheating, which phenomenon has probably not been observed before in temperature-time curves of this kind. Accordingly Ac_1 appears definitely as a refrigerescence, or decalescence point. The effect is somewhat more

distinct in curve A (pear-shape) than in B, but the difference is insignificant.

More striking is the following difference:—In B the Ac_1 point occurs at 695-700 degrees Cent., or about 25-30 degrees higher than Ar_1, which is in accordance with common experience—gained for the most part with cylindrical specimens. On the contrary, in

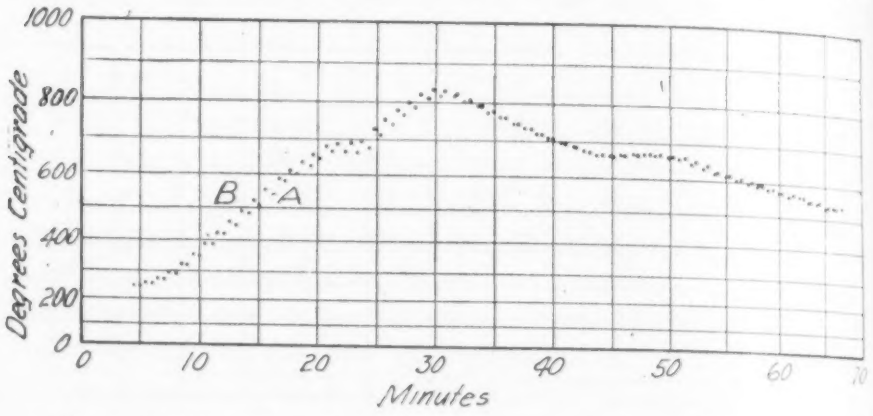


Fig. 6—Heating and Cooling Curves from the Same Specimens as were Used in Fig. 5. Plotted on the Same Coordinates. Curve (B) is that of the Cylindrical Specimen; Curve (A) is that of the Pear-Shaped Specimen.

curve A Ac_1 appears at 670-675 degrees Cent., i. e., very little higher than the Ar_1 temperatures.

Fig. 6 gives the result of another registration taken in the second way. The curve A refers to the pear-shaped specimen, and the curve B to the cylindrical. Again it is observed that Ar_1 occurs sensibly at the same temperature in both cases (about 665 degrees Cent.); the transformation horizontal is a trifle longer in the B-curve, no doubt owing to the greater mass of specimen B.

The heating curve of B is throughout higher than that of A. Also in this case A shows a sharp Ac_1 point at nearly the same temperature as Ar_1, while that of B is less sharp and considerably higher. In a repetition of this registration the two curves lay closer together, but in any case the Ac_1 point appeared much more sharply for A than for B.

These comparative experiments have shown the pear-shaped specimen to be decidedly superior to the other. It is, however, a still more striking fact that as sharp angles have appeared in the heating curves as in the cooling curves: evidently on account of the excellent contact secured between the specimen and the thermo-junction.

It is a matter of general experience that cooling curves are much more characteristic and definite than heating curves, but up to the present time no logical explanation of this appears to have been given. As a matter of fact, however, in the foregoing we have obtained heating curves which are scarcely less sharp than the cooling curves; no pronounced difference appears, provided the contact between the specimen and the thermo-junction be an intimate one. If, however, the contact is less perfect, the circumstances will be as follows: When heating an electric resistance furnace the current of course must heat not only the interior, containing the specimen, but also the external part of the furnace; the heating winding accordingly is at a higher temperature than would be necessary for the inner part itself. Consequently—if not in perfect contact with the specimen—the thermo-junction is apt to become heated above the actual temperature of the specimen. On the contrary, on cooling, the temperature is considerably more uniform (the heating winding now having just the temperature of the furnace), and there is, therefore, little reason for the temperature of the thermo-junction deviating considerably from that of the specimen.

Here the following remark may be made: Supposing we have to cool a body below the temperature of its surroundings, naturally some cooling device—say a cooling coil—must be used. In this case a cooling curve will be less sharp than a heating one, on account of the fact, that the necessarily much lower temperature of the cooling coil will easily cool the thermo-junction in an undue manner. The heating curve on the contrary will be much sharper, as in this case no cooling effect will be necessary, and the temperature consequently will be a considerably more uniform one.

The consequence of the above argument is the following: If the sharpest possible heating curve is required, the furnace employed should be heated from the outside, i. e., the heating winding must be located as far as possible away from the specimen and thermocouple. Especially in the case of a perfect contact between thermo-junction and specimen, one will then, no doubt, obtain as sharply developed curves for heating as are usually obtained on cooling.

Finally the following may be emphasized: As we have seen, a perfect contact between specimen and thermo-junction is always

to be recommended, but it is indispensable in all such cases where the thermal changes—as in most special steels—are characterized by internal inertia or are in themselves trifling. When it is not possible to obtain a direct metallic contact between specimen and thermo-junction but some kind of insulating layer (i. e., a protection tube) cannot be dispensed with, then the procedure should be as follows: The thermo-junction is strengthened by welding on to it a well conducting disc (for example, silver or platinum), which should press tightly against the inside of the protection tube, while the external surface of the latter should fit as closely as possible to the metal specimen.

Summary

As guiding principles for obtaining more sharply defined thermal curves the following are emphasized:

1. The specimen should possess, as far as possible, a spherical form. A pear-shape, however, as a rule, is to be recommended, as otherwise the heat conduction along the pyrometer exercises too strong an influence. If it is necessary to use a cylindrical specimen, then all edges should be rounded off.

2. The thermo-junction must be located at the center of the sphere; also in the case of specimens of other shapes it must be placed as centrally as possible.

3. The obtaining of perfect contact between thermo-junction and specimen is most important (see, for example of method, Fig. 4). If this is not possible, and some insulating layer must be used, the junction should be strengthened so as to make a reasonably good contact.

4. To obtain sharp heating curves it is essential to avoid having the heating winding, or whatever is being used, in the neighborhood of the specimen and thermo-junction.

The experiments described under heading 2 were carried out by K. G. Lund, the remainder by W. H. Dearden, assisted by P. Sederholm. The analysis given under heading 4 was carried out by M. Liljefors, mining engineer, at the Royal School of Mines of Stockholm.

SECONDARY CRYSTALLIZATION IN IRON-CARBON ALLOYS

By V. N. Krivobok

Abstract

That the structure of cast steel objects to be subjected to heat treatment is a matter of importance, should be fully realized. The contents of this paper embrace this question of cast steel structures and provide the description of the two extreme types of such structures.

The genesis of the formation of these types is traced back to the zone of its origin and formation and is discussed in terms of the iron-carbon diagram.

The current ideas concerning the subject supplemented by author's observations and subsequent deductions—which can be found at the end of the paper—are discussed at length.

THE question of crystallization of iron alloys has lately attracted wide and well-deserved attention. Several eminent metallographists have devoted their time and energy to the study of this most important subject and their results have brought new light to our knowledge of the phenomenon of solidification and crystallization of metals. A paper[1] presented by Colonel Belaiew before this convention is a brief summary of his brilliant researches along the same lines. The present author, being deeply interested in the subject, has conducted a series of independent researches, the results of which are here summarized.

In the light of our knowledge, based on experimental evidence, we distinguish three zones or areas through which the alloy passes from the liquid state down to room temperature. The nomenclature is due to Colonel Belaiew and the three zones are known as the zone of primary crystallization, the zone of granulation and the zone of secondary crystallization. Numerous publications on the

[1]Colonel N. T. Belaiew, "The Granulation Hypothesis and the Delta-Gamma Change in Iron-Carbon and Iron-Nickel Alloys," Transactions of the American Society for Steel Treating, June, 1924, Vol. V, page 549.

A paper presented before the Boston Convention of the Society, September, 1924. The author, Dr. V. N. Krivobok, member A. S. S. T., is research associate, Bureau of Metallurgical Research, Carnegie Institute of Technology, Pittsburgh.

questions relating to the first two zones are to be found elsewhere. The present writer has devoted much of his time to the study of the secondary crystallization in metals, mostly in iron-carbon alloys.

As we believe at present, at the end of granulation the whole mass of the alloy is converted into new grains or granules mutually limiting each other. When the cooling alloy reaches the critical range a new transformation, which may be called physical, commences, namely, that of the decomposition of the solid solution. The decomposition consists in the ejection of the excess of one of the components (in case of hypoeutectoid steel, ferrite) and in the subsequent transformation of the solid solution into an aggregate of constant composition, this transformation taking place at a constant temperature. The products of the decomposition just described will be (1) ferrite (in hypoeutectoid) and cementite (in hypereutectoid steels) and (2) the aggregate known as pearlite, which consists of alternating particles or lamellæ of ferrite and cementite.

The important consideration for us to ponder at present is that the excess constituent or proeutectoid element rejected from the granules of different orientation can assume different locations so different in fact that alloys of an identical chemical composition can display two absolutely different structures. The ejected excess constituent (in the case of hypoeutectoid steels it will be ferrite) can be located in one of the following ways:

1. At the boundaries of the former austenitic granules (net work structure)
2. Between the cleavage planes of the granules (cleavage or Widmanstätten structure)
3. Parallel to the axis of the dendrites reminding one of the crystal skeletons of the macrostructure (structure of large crystals).

Apparently there are certain conditions of solidification and cooling which govern the appearance of one or the other of the structures mentioned.

Colonel Belaiew has proposed, on the basis of his experiments, a theory which can be best related in his own words:

"First," says Col. Belaiew,[2] "a thin layer of a new deposit

[2]Crystallization of Metals, London, 1922, p. 66.

(excess constituent) will be formed around every grain. Gradually that layer or film will become a kind of envelope. On a section owing to such envelope polygonal boundaries between the grains will look like so many meshes and the whole structure will assume a cellular or network character.

"If the whole of the secondary deposit had time to segregate in this way a pure network structure would ensue. The main condition, therefore, is a relation between the size of the grain and the speed of the secondary crystallization as would make such a segregation not only possible but most likely.

"It is easy to see that the larger the size of the grains the more difficult it is to expect that the whole of the secondary deposit would collect at the boundaries. If, for instance, the process were to proceed at a more accelerated pace a certain proportion of the deposit would be forced to crystallize out on the spot, that is, not on the boundary but in the middle of the grain. In such a case the habit and orientation of the crystalline matter would be the dominant factors and the deposits would arrange themselves parallel to the cleavage planes."

Speaking in terms of the equilibrium diagram, then, the cleavage or the Widmanstätten structure will appear according to Belaiew if;

1. The granulation zone was traversed in such a manner as to produce large grains, and
2. If but a short time is allowed to an alloy for passing through an area of secondary crystallization.

When, on the other hand, plenty of time is allowed for the secondary crystallization, that is to say, when the critical range is covered very slowly, the whole of the ferrite will (according to Colonel Belaiew) travel in some manner through the grain and collect at the boundaries.

Certain experiments and observations have sowed doubt in the present writer's mind as to the correctness of the theory proposed by Colonel Belaiew, (and since adopted in many text books on metallography) and the investigation of the question ensued.

It is quite possible that not only the rate of cooling but also other factors such as, for instance, chemical composition (the amount of carbon and also the presence of other elements and

impurities) and the temperature of melting, have some influence upon the final structure of the steels. In fact, the investigation conducted has shown that the factors mentioned influence the structure of cast metal in different ways. In the present paper, however, the author will consider only one factor, namely, the rate of cooling of an alloy through

a. Granulation zone
b. Zone of secondary crystallization.

The consideration of other factors, it is hoped, will be communicated later on. In order to eliminate the influence of the chemical composition a series of pure electrolitic iron-sugar charcoal alloys were prepared. Several alloys of as nearly identical composition as possible were prepared and allowed to solidify and cool down in such a way as to comply with the different conditions outlined by Colonel Belaiew.

The chemical composition, actual conditions of cooling and the resultant structure of cast alloys are summarized in the following tables:

Table I

		Carbon	*Conditions of Cooling*
	Fig. No.	*Per Cent*	
M-37	1 and 2	0.40	Cooled rapidly through granulation and secondary crystallization zone.
M-31	3 and 4	0.415	Slower cooling through granulation and rapid through secondary crystallization zone.
M-27	5	0.350	
M-34	6	0.335	Very slow solidification, rapid cooling through granulation and secondary crystallization zone.
M-40	7 and 8	0.50	Rapid solidification, rapid cooling through granulation and secondary crystallization zone.
			All specimens showed a network structure.

The melts just described were made according to one of two schemes:

a. Rapid* cooling through the granulation zone and the zone of secondary crystallization
b. Slower cooling through granulation but rapid through critical range down to room temperature.

In all cases the microstructures of the cast metal were of network type and contrary, therefore, to the current theory concern-

*By "rapid" is meant cooling from the liquid state to below the critical range in about 15 minutes.

ing the secondary depositions in hypoeutectoid steels. These findings justified a new series of experiments in which the mode of cooling of additional melts through the critical range was changed, namely, the alloys were allowed to solidify through this range at the increasingly slower rate.

The first melt of this series contained 0.57 per cent carbon (M-39) (Fig. 9). As soon as the steel, prepared in the same electric vacuum furnace solidified, its temperature falling rapidly, the electric energy impressed upon the furnace was so adjusted that the temperature of the steel was well above the critical range. From this starting point[3] the cooling proceeded in such a way that it took 1 hour and 10 minutes for the ingot to attain the temperature of about 250-300 degrees Cent. After the examination it was found that the structure of this sample (Fig. 9) does not differ in any essential way from the sample (M-27), Fig. 5, both of them (a) display a network structure, (b) the interior of the grain is not pearlitic but sorbitic, (c) their structure as cast can easily be mistaken for that of steel of higher carbon content.

The two next melts were prepared of as nearly a similar composition as possible. Both of them were allowed to solidify in the same way. But then the alloy (M-40) (carbon 0.50 per cent) (Figs. 7 and 8) was cooled to above the critical range in 15 minutes, by gradually decreasing the power and finally, by shutting off the power entirely, it was cooled rapidly through the range.

The other alloy (M-45) (carbon 0.44 per cent) (Figs. 10 and 11) on the other hand was cooled from solidification down to dull red heat in 5 hours and 30 minutes.

The photographs of (M-40) (Figs. 7 and 8) show the distinctive features of network structure, with occasional particles of ferrite starting here and there from the ferritic boundaries between the grains.

On the other hand the ingot (M-45) whose microstructure is shown in Figs. 10 and 11 displays a perfect sample of the class of structures which it is accepted to call "cleavage" or "Widmanstätten." These photomicrographs show a grain which, according to our belief, was an austenitic solid solution grain above the critical range but now is completely converted into an aggregate of ferrite-pearlite, with the particles of each constituent oriented in

[3] It should be noted that this alloy (M-39) was cooled relatively slowly from the temperature from which alloy M-27 was cooled rapidly.

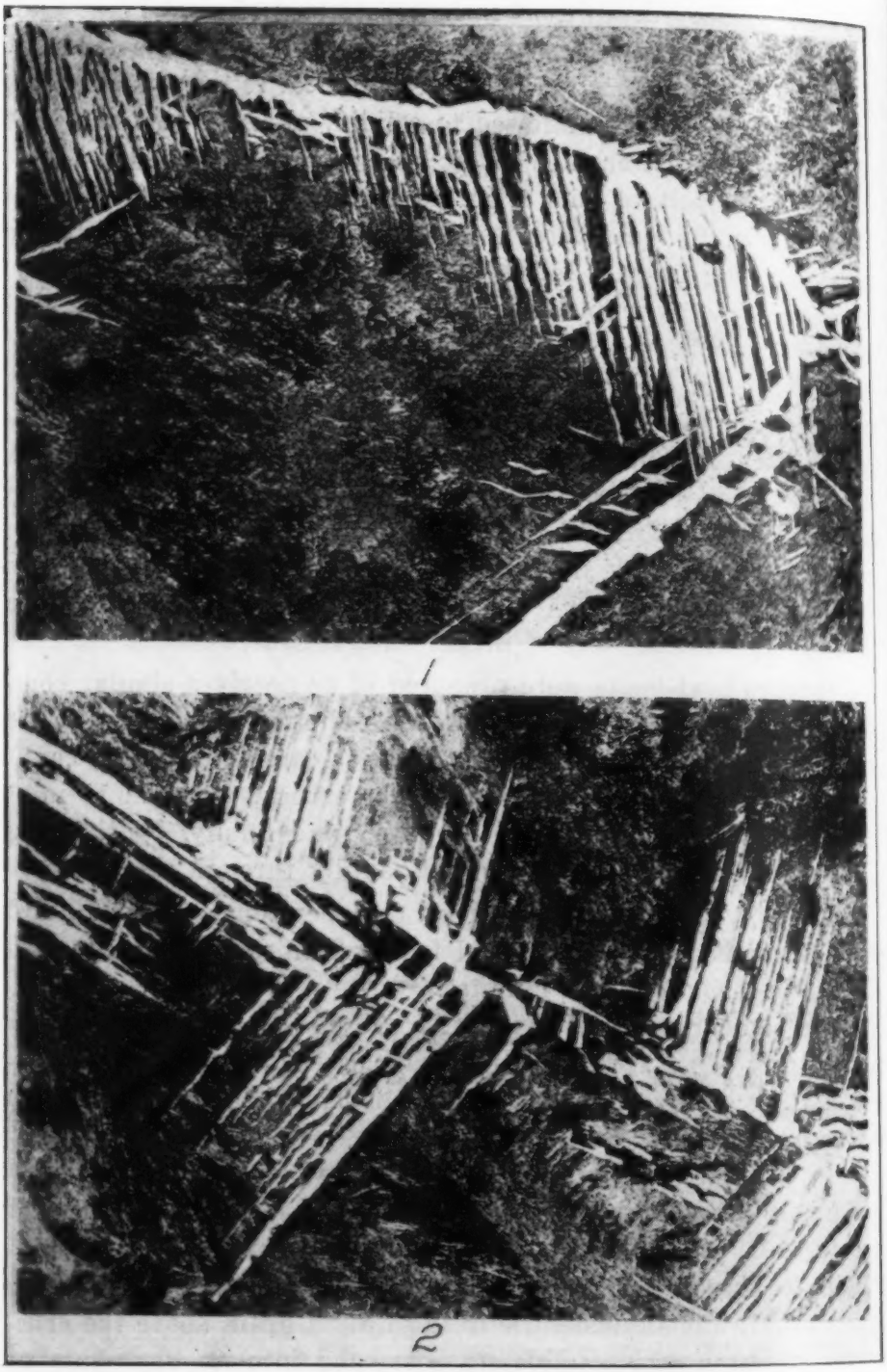


Fig. 1—Photomicrograph of Alloy M 37, Showing Ferrite Boundaries Between 3 Grains. 100x. Fig 2—Photomicrograph of Alloy M 37, Showing Ferrite Grain Boundaries and Shoots of Ferrite Projecting into the Grain. 100x.

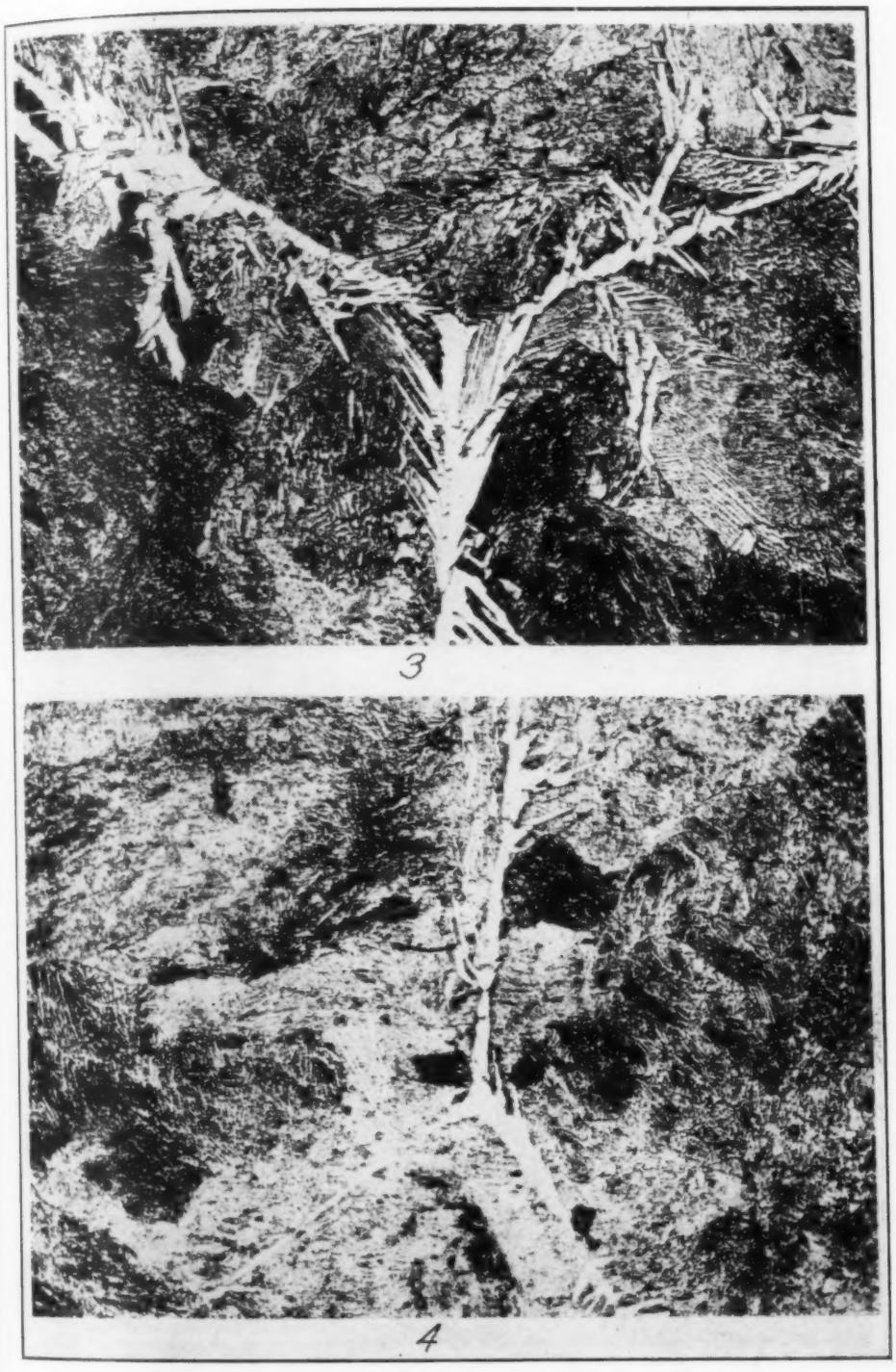


Fig. 3—Photomicrograph of Alloy 31 Showing Ferritic Grain Boundary Between 3 Grains. Note the Particles of Ferrite Projecting toward the Inside of the Grain. 100x. Fig. 4—Photomicrograph of Alloy 31 Showing another Section of the Specimen Shown in Fig. 3. 100x.

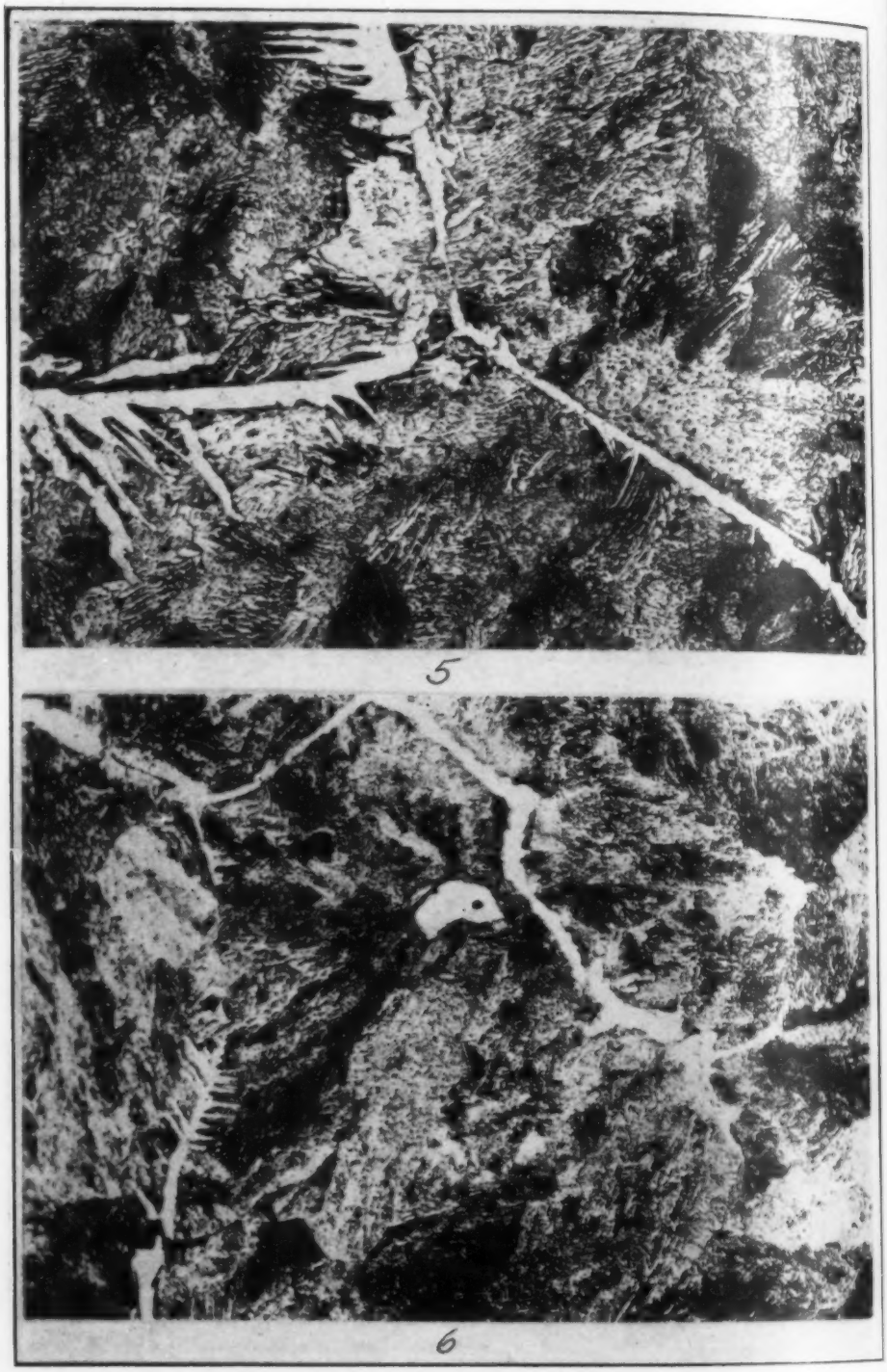
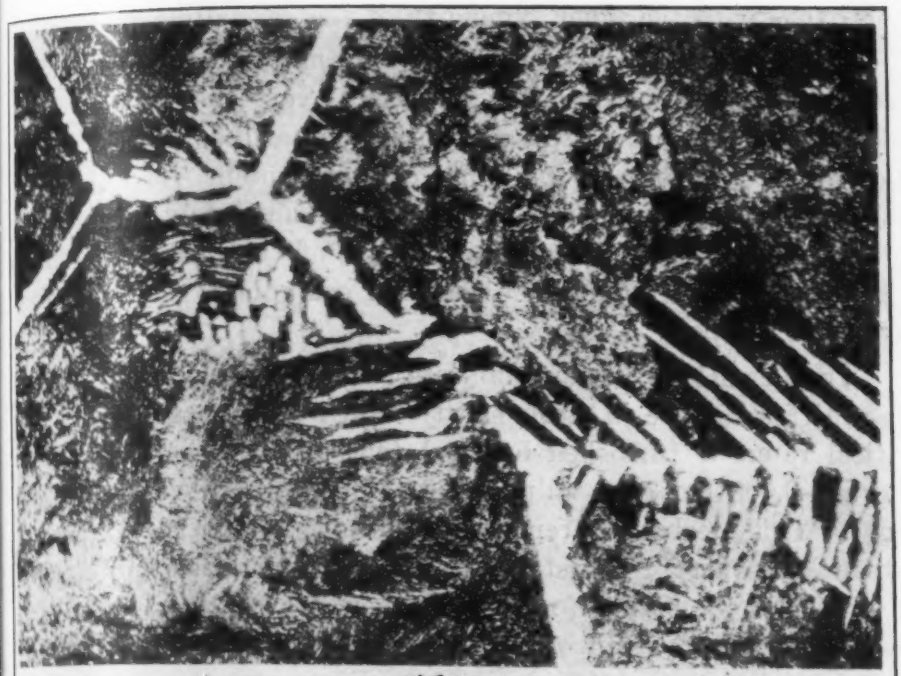


Fig. 5—Photomicrograph of Alloy M 27 Showing Ferritic Boundaries in a Net Work Type of Microstructure. 100x. Fig. 6—Photomicrograph of Alloy M 34 Showing a Ferritic Net Work Between Sorbitic-pearlitic Grains. 100x.



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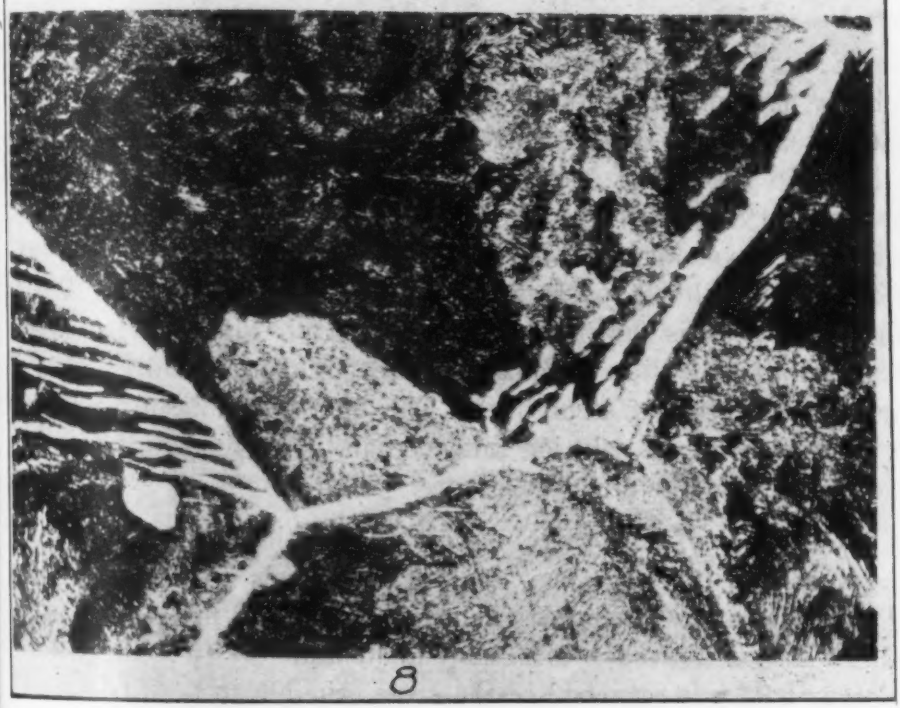

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Fig. 7—Photomicrograph of Alloy M 40 Showing Ferritic Net Work Between Sorbitic Grains. 100x. Fig. 8—Photomicrograph of Alloy M 40. This Photomicrograph is Similar to that in Fig. 7 but Taken of a different Area of the Specimen. 100x.

accordance with the inner symmetry of the crystalline grain.

In order to be reasonably assured that the reproduction of cleavage structure through the medium of very slow cooling down below the critical range was not an accidental occurrence, another alloy of approximately the same carbon content (M-50, carbon —0.48 per cent) was prepared in a way absolutely identical to that of ingot M-45. The microstructure of the melt is shown in Fig. 12 and presents another beautiful example of almost perfect "cleavage" type.

Another attempt to substantiate the occurrence of "cleavage" type microstructure in steels slowly cooled through and below the critical range is furnished by steel (carbon—0.44 per cent, phosphorus—0.005 per cent, sulphur—0.03 per cent, silicon—0.235 per cent). This steel was prepared in the electric furnace in ingots two inches square. The steel was thoroughly melted and allowed to solidify in the furnace, requiring 8 hours to cool from the molten state to room temperature. The examination of this steel discloses a perfect cleavage or "Widmanstätten" structure. (Photomicrograph Fig. 13.)

E. L. Reed, assistant to Dr. Sauveur and Carnegie Research Scholar, had prepared for his own purpose a series of iron-carbon alloys varying in composition from 0.40 to 0.90 per cent carbon. All of the steels were prepared in the vacuum furnace and after melting very slowly cooled in the furnace. The 0.40 per cent carbon alloy is shown in photomicrograph Fig. 14. Its structure is that of an almost perfect cleavage type. Carbon steel of 0.60 per cent carbon is shown in photomicrograph Fig. 16.[5] The microstructure of this alloy is again a perfect and beautiful example of the cleavage class of structures. The ferrite had been given time to be thrown out of solution not only at the grain boundaries, but also in between the cleavage planes.

A number of steel melts were made by the writer in the early stages of the investigation. All of the steels were melted in a 50-pound electric resistance furnace. After the metal was ready, half of it was poured into a sand mold and left to solidify there. Another half was returned in the same crucible to the furnace and was very slowly cooled. The period of cooling extended well over 18 hours. In this way two different rates of cooling were imposed upon steel of absolutely identical chemical composition. The re-

sults were rather instructive. In Figs. 16 and 17 is shown the cleavage structure of the steel which was allowed to solidify in the furnace. The structure of another ingot poured into a sand mold presents an entirely different structure—it is a more or less typical structure of the steel castings in which the orientation of the ferrite presents a combination of the network and cleavage structures. (Fig. 18.)

On the basis of the results obtained from experimenting, and after a careful study of the existent theoretical knowledge, and after account of the recent development in the field has been taken, theory presently to be enunciated does not seem to be entirely without foundation.

Discussion

When we speak of steel or, to take a simpler case, of an iron-carbon alloy just below "solidus," we understand in this connection a solid solution of carbon and iron. We have strong reason to believe, on the ground of the latest researches of Westgren,[4] that above the temperature of 1450 degrees Cent. (2642 degrees Fahr.) we have delta iron modification with body centered cubic lattice, while below that temperature we find gamma iron with face centered cubic lattice.[5] This transformation of one atomic arrangement to the other is sufficient reason, as regarded by some, to account for the recrystallization in the solid state, which was so much discussed and called "granulation."

Whether the passing of the delta form of iron into another or gamma form is the reason for granulation, or whether some other physico-chemical phenomena are involved, the writer is not prepared to state. The existence of gamma allotropic modification appears to be established beyond doubt, and the zone of existence of the solid solution of carbon and gamma iron appears to be the natural starting point for the considerations concerning the changes which take place on cooling to room temperature.

Our present conception of the solid solutions is not altogether clear. Within such a solution we find two kinds of atoms, which we call respectively solvent and solute atoms. The general char-

[4] *Proceedings.* American Iron and Steel Institute, 1923, p. 1021.

[5] According to Mr. Belaiew "The Granulation zone is a zone of the true gamma iron. Zone of primary crystallization one of delta iron." *Journal* of Aeronautical Engineers, 1920, Vol. I, p. 23.

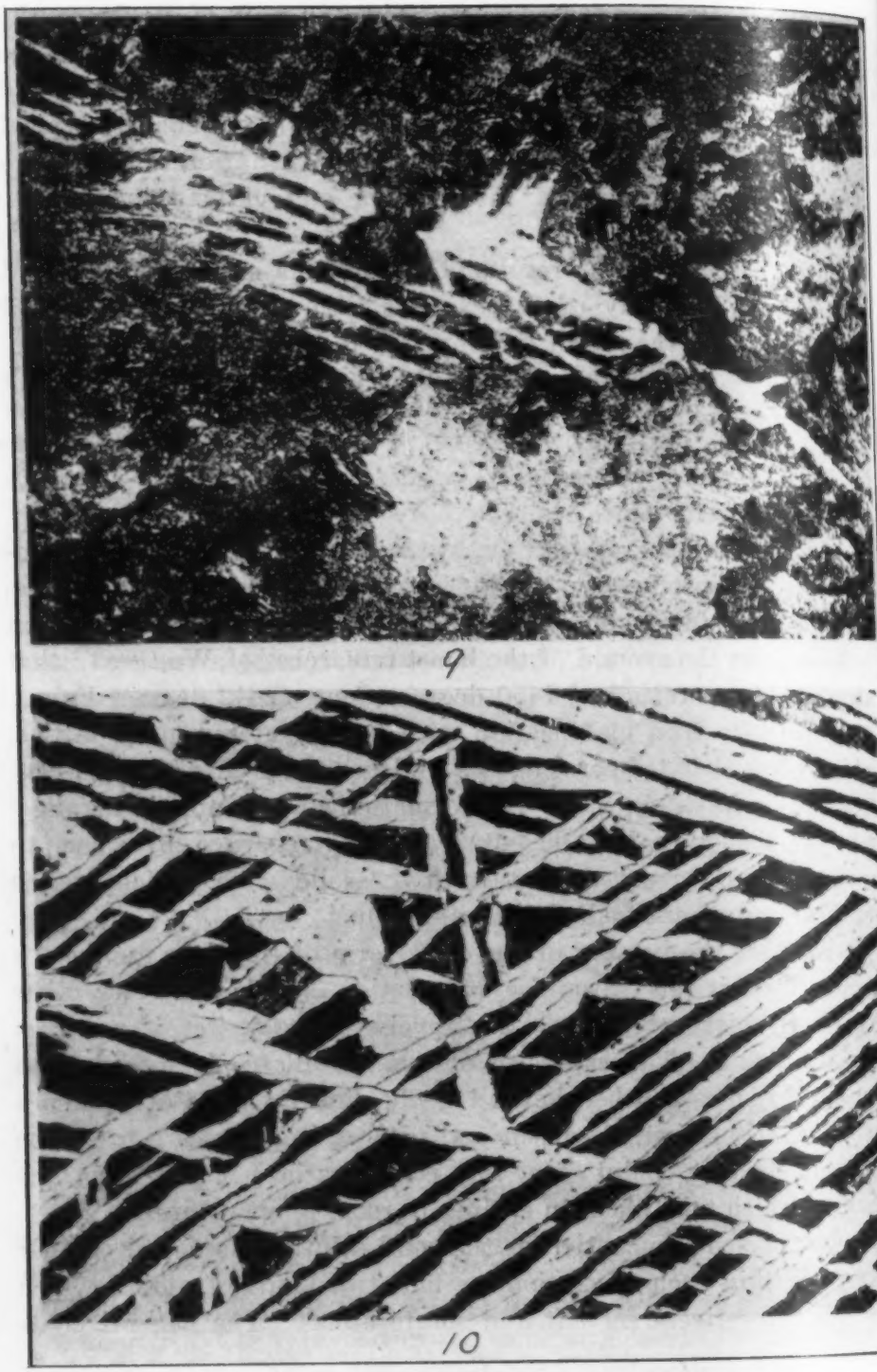
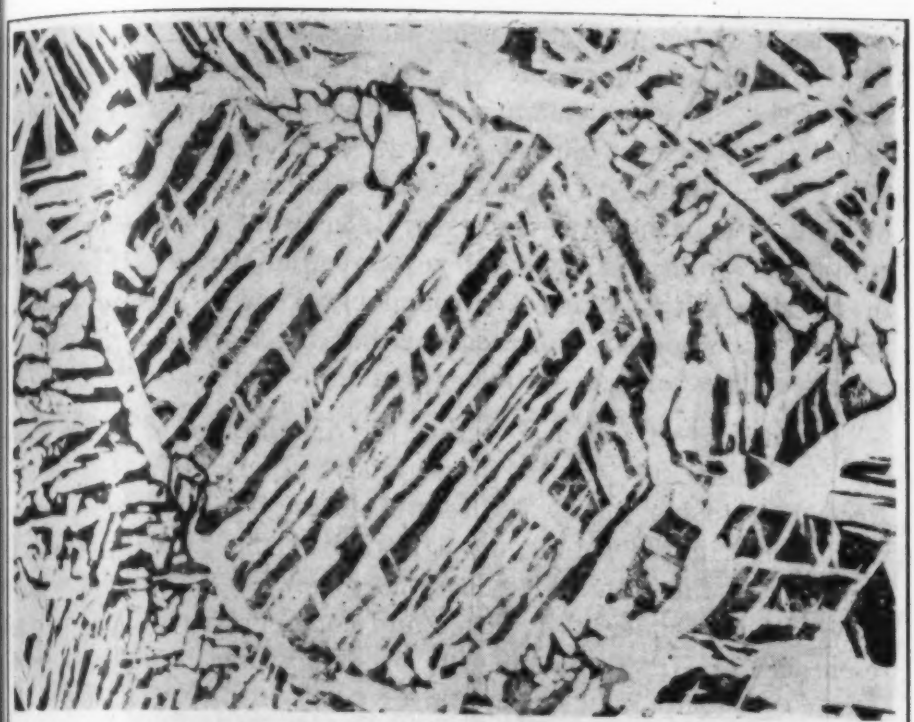


Fig. 9—Photomicrograph of Alloy M 39. 100x. Fig. 10—Photomicrograph of Alloy M 45. Specimen was Slowly Cooled Through Critical Range. This Photomicrograph Shows the "Cleavage" or "Widmanstatten" Structure. 100x.



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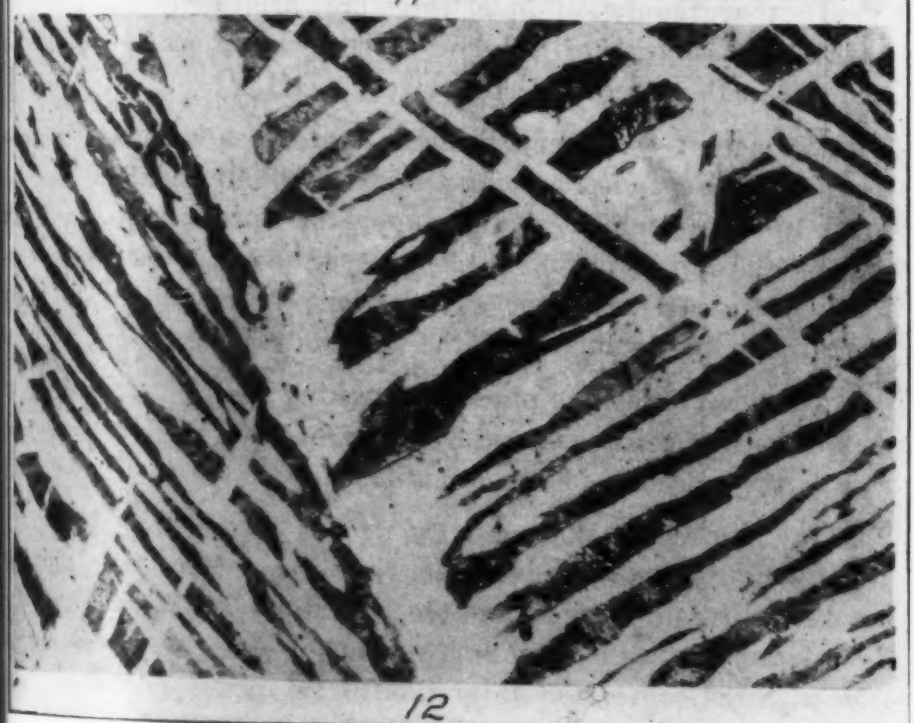

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Fig. 11—Photomicrograph of Alloy M 45 Showing a Grain of "Cleavage" Structure Surrounded by Ferritic Boundaries. 50x. Fig. 12—Photomicrograph of Alloy M 50 Showing Cleavage Structure. 100x.

acteristics of the pure crystalline metals apply with equal strength to the solid solutions: in both cases the atoms are found to be arranged in a perfect manner in full conformity with their established space lattice. Such space lattices have been determined for many pure metals. In the case of solid solutions, however, the obtainable experimental results are somewhat confused and difficult to interpret. We are not yet sure whether all solid solutions in metallic alloys which are commonly known in practice, have lattices for their solvent atoms, either the normal lattice of the pure metals or of a definite compound.

For our latest idea concerning the distribution of solute atoms we are indebted to the researches of Dr. W. Rosenhain. According to his theory the solute atoms simply replace the solvent atoms in the actual space lattice of the solvent metal. In view of the fact that this theory is somewhat supported to some extent by experimental evidence and corroborated by quite recent researches of Dr. Tammann, the present writer is inclined to accept it as a temporary conception.

In the granulation zone, therefore, arbitrarily speaking, we have a solid solution of iron and carbon with atoms of carbon distributed in the space lattice of solvent metal.

We accept as a general thesis that when a lattice becomes distorted or expanded beyond a certain definite point, it tends to break up, the results depending upon the cause of distortion. It will be the liquid phase, in the case of melting; an amorphous solid in the case of plastic deformation; or a sound solid phase when the limit of solubility in the solid state is passed.

When we study the phenomena taking place in the cooling of metals down to room temperature we realize that the last mentioned case is the rejection of alpha-ferrite, only stated in the terms of atoms.

Hence we can conceive that when the Ar_3 or Ar_{3-2} point is reached, the first steps in the rejection of ferrite are the dissociation-parting of iron atoms from the space lattice of gamma iron with the consequent formation of the new solid phase. The atoms that find themselves at liberty, so to speak, probably coalesce so as to form at first ultra microscopic particles. These particles

may, later on, form kernels of a larger size and be visible under the microscope.[6]

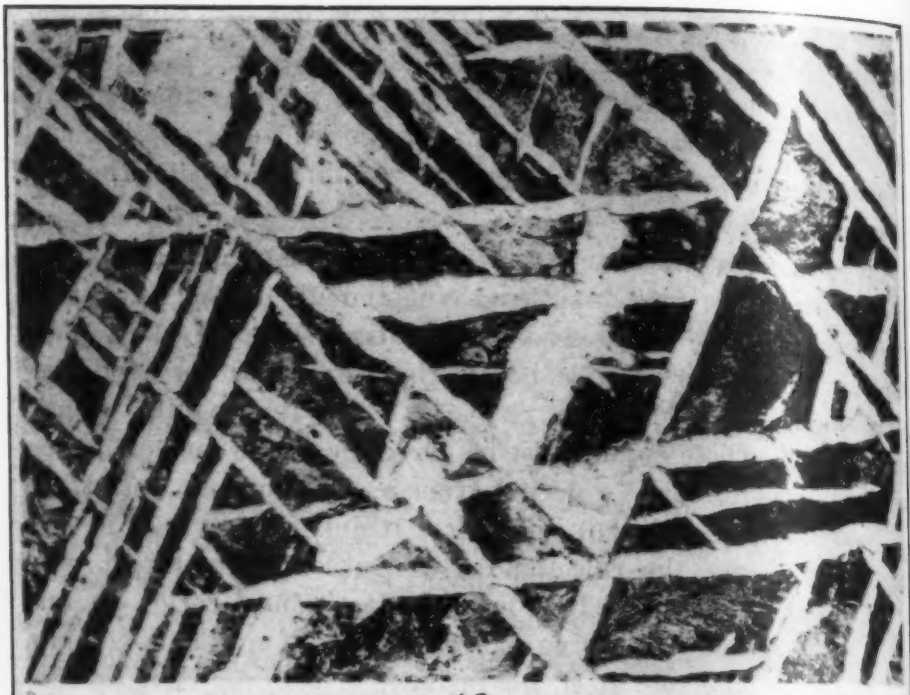
These visible kernels or particles are the pro-eutectoid constituent in low carbon steels. As soon as we notice their presence and occurrence we speak of "the rejection" of ferrite or of "the secondary crystallization."

We know that whenever the rejection of the excess constituent occurs, it requires a certain length of time to be accomplished. Should this time be suppressed, no rejection will take place. We know also that in crystalline bodies there exist certain bonds between the atoms, which are responsible for the regular atomic arrangement. These bonds must be overcome at the moment when the excess constituent is rejected from a solid solution. If these bonds are partially disrupted,—as we think is the case in the amorphous phase,—the rejection of excess solid constituent may be somewhat facilitated. Keeping this last consideration in our mind, let us follow the cooling of the number of grains of gamma iron in a hypo-eutectoid steel, for instance of 0.50 per cent carbon.

Upon reaching the Ar_3 or Ar_{3-2} point the excess ferrite is rejected. The most logical place for the inception of this rejection to commence will be at the grain boundaries, where according to the most commonly accepted belief we have a network of the metal in the "amorphous" state. The writer is inclined to regard the presence of the boundaries as a fact which exerts a powerful influence. Under the conditions of cooling which are most unfavorable for the rejection of excess constituent we almost never fail to see the ferrite rejected and collected at the grain boundaries: an artificial process of quenching is of course an exceptional case. The suppression of time for the rejection of the excess constituent is this "unfavorable" condition.

Hence in the steels quickly cooled we would expect to find the ferrite at the grain boundaries only, and since only a part of the ferrite has been rejected, we would form the opinion that the steel in question contains more carbon than it actually does. Such a theoretical consideration is strongly supported by the experimental evidence: among many melts already discussed by the writer, melt M-40 (Figs. 7 and 8), is, perhaps, the most characteristic. This

[6] The writer wishes to intimate that the theoretical conceptions submitted concerning atoms and their arrangement are to be regarded not as an established doctrine, but as a more or less speculative theory, which can be readily discarded as soon as we have a better one.



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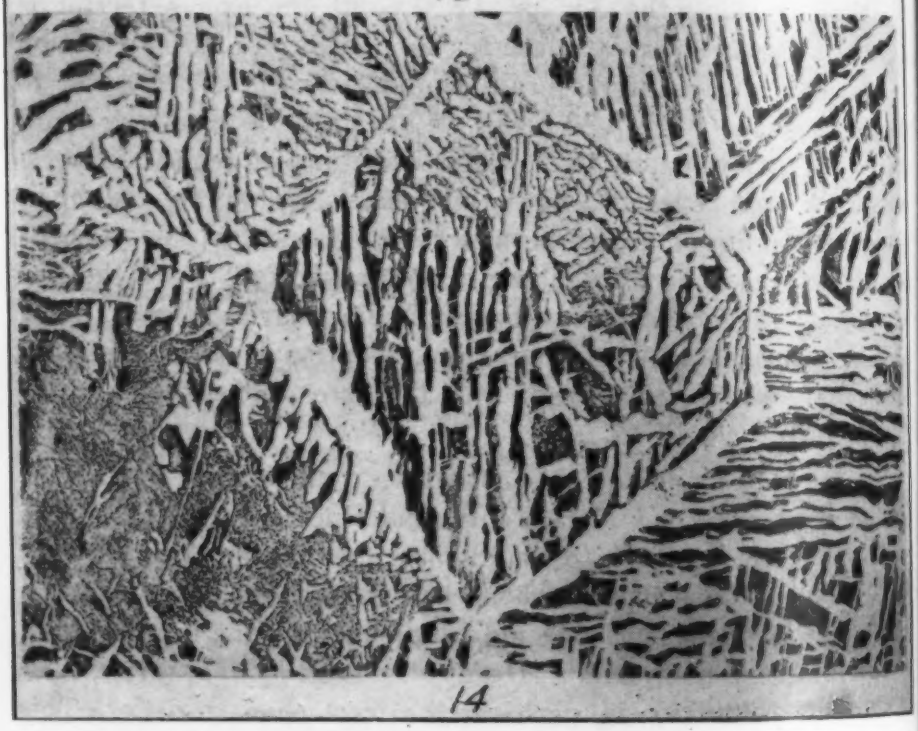

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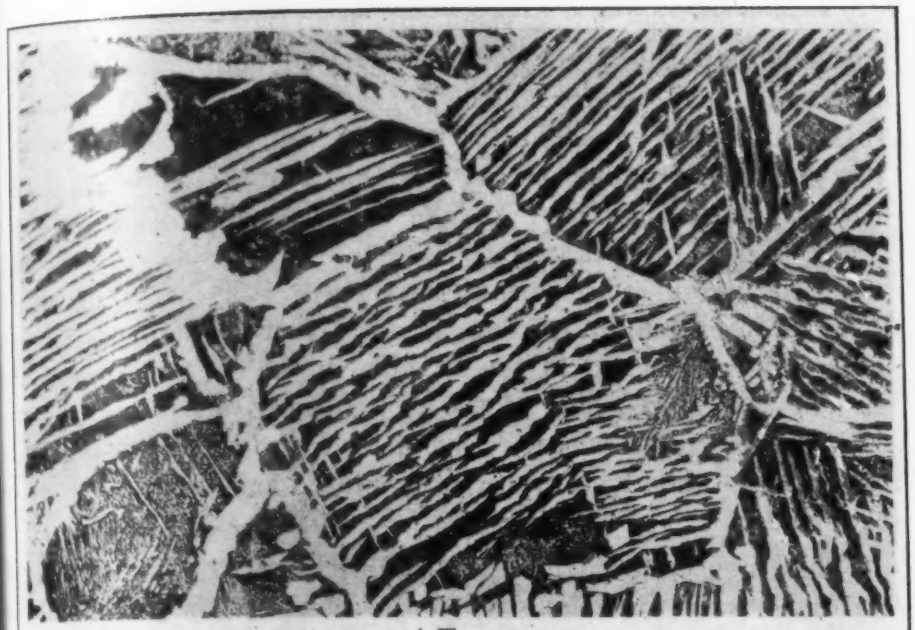
Fig. 13—Photomicrograph of Commercial Steel Having a Carbon Content of 0.44 Per Cent. This Specimen was Slowly Cooled Through Critical Range and Shows the Widmanstatten or Cleavage Type Structure. 100x. Fig. 14—Photomicrograph of an 0.40 Per Cent Carbon-Iron Alloy Slowly Cooled Through the Critical Range. 100x.



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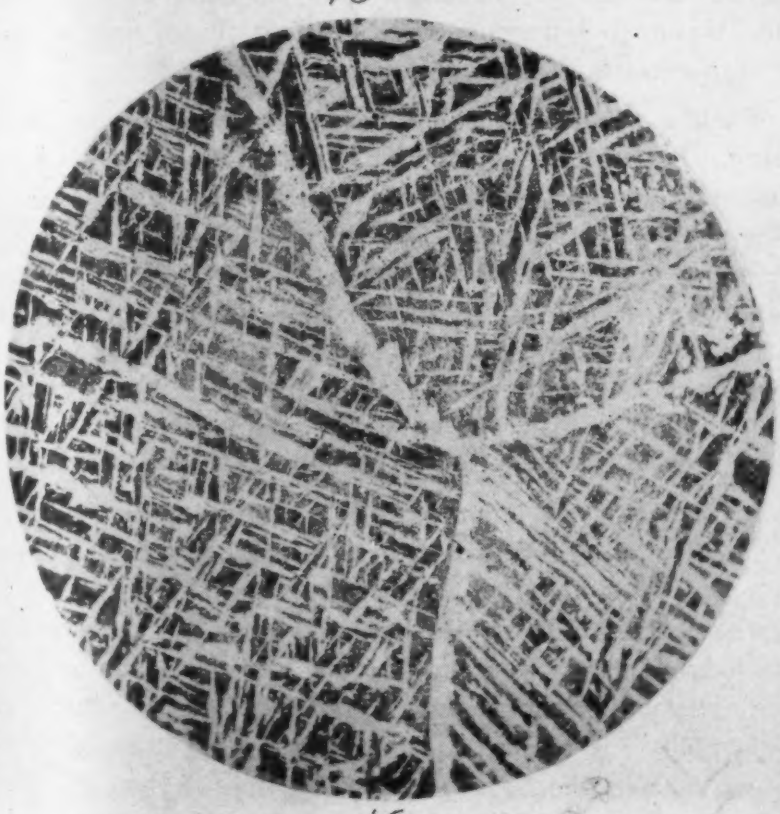

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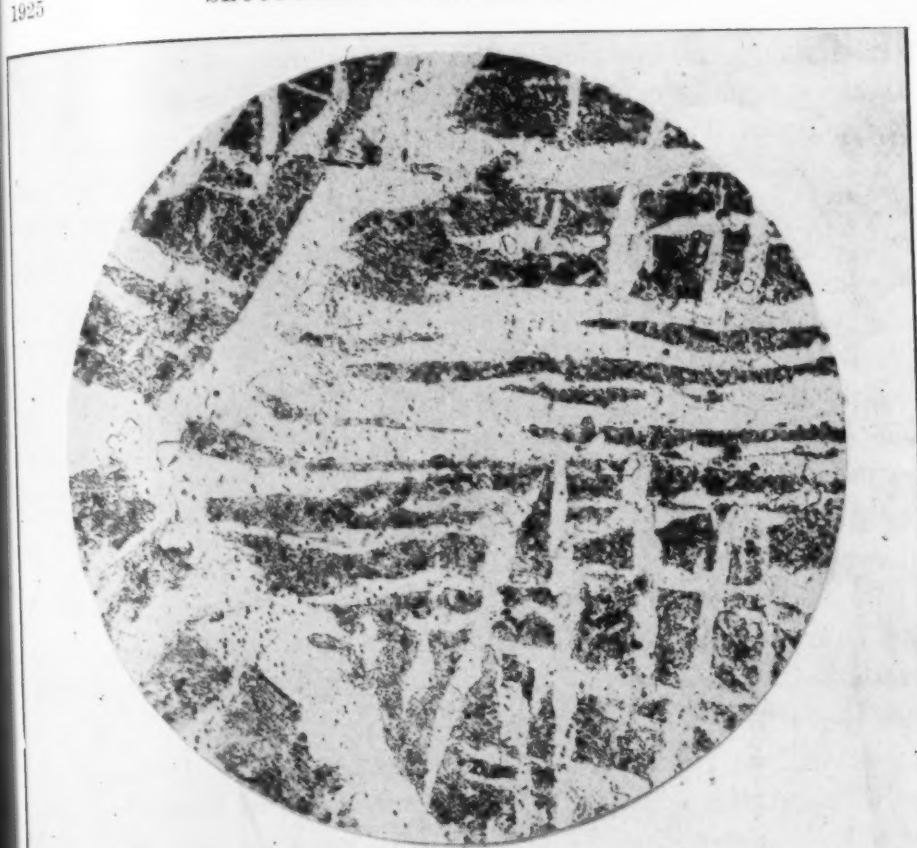
Fig. 15—Photomicrograph of an 0.60 Per Cent Carbon-Iron Alloy which Has Been Slowly Cooled Through the Critical Range. 100x. Fig 16—Photomicrograph of an 0.60 Per Cent Carbon-Iron Alloy as Cast. 28x.

steel of 0.50 per cent carbon (by analysis) was cooled rapidly through the granulation and secondary crystallization zone. The results of such cooling were: (1) only partial throwing out or rejection of pro-eutectoid ferrite, which in turn shows (2) that this steel can be mistaken for 0.60-0.70 per cent carbon. A very striking illustration of the same kind can be presented by the writer in the case of commercial steel of the following composition: carbon 0.50 per cent; manganese 0.59 per cent; silicon 0.350 per cent; sulphur, 0.031 per cent; phosphorus 0.027 per cent. This steel was melted in the crucible in the electric furnace, and after it was ready, half of the molten steel was poured into another crucible, placed on the floor of the foundry and left to solidify there. The weight of the ingot produced in this way was about 15 pounds.

The structure of the steel is illustrated in Figs. 19 and 20. Hardly anyone would guess that this steel contains only 0.50 per cent carbon, but the chemical analysis cannot be disputed and, hence, we must be reconciled to the fact that a part of the ferrite has been retained within the grain.

Such a retention, as has been stated, is due to too rapid a cooling. Let us now consider a hypothetical case, when our alloy of 0.50 per cent carbon steel was cooled somewhat more slowly than in the previous case, but not slowly enough, nevertheless, to cause the complete ejection of all the excess ferrite. To imagine such a condition of cooling we do not need to give any actual figures relating to the rate of cooling, but to assume, let us say, arbitrarily, a cooling slower than the one which produces the thin ferrite network structure, which surrounds the grains.

We can state without hesitation, that a slower cooling means a more favorable condition for the rejection of excess ferrite and, consequently, *more* ferrite will be rejected, though, perhaps, not all. It is conceivable that this extra ferrite will come out of solution somewhere within the grain, but it is more probable to expect it to be lodged at or near the ferritic boundaries already existent. It is a matter of common knowledge that if we introduce a crystalline particle of a certain matter in a super-saturated solution of the same matter, the falling out of solution of the crystalline matter in question will take place at the particle introduced. Our troostitic or sorbitic grain is such a super-saturated solution. The



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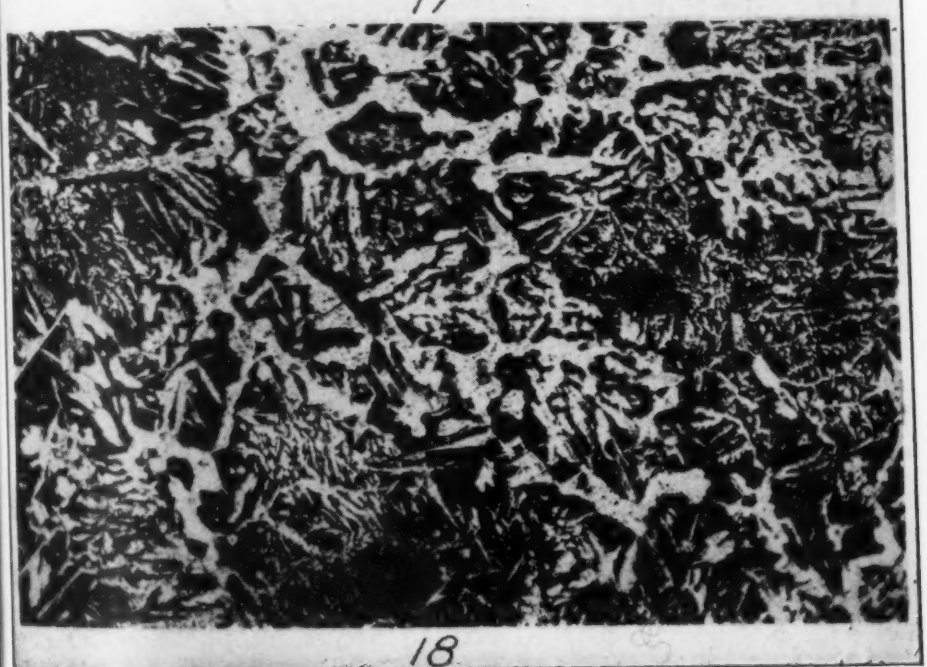

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Fig. 17—Photomicrograph of an 0.60 Per Cent Carbon Steel Showing the Cleavage Type of Structure Observed in this Steel which was Allowed to Solidify in the Furnace. 100x.
Fig. 18—Photomicrograph of a Steel Specimen of the Same Composition as Shown in Fig. 17 but Allowed to Solidify in a Sand Mold. 100x.

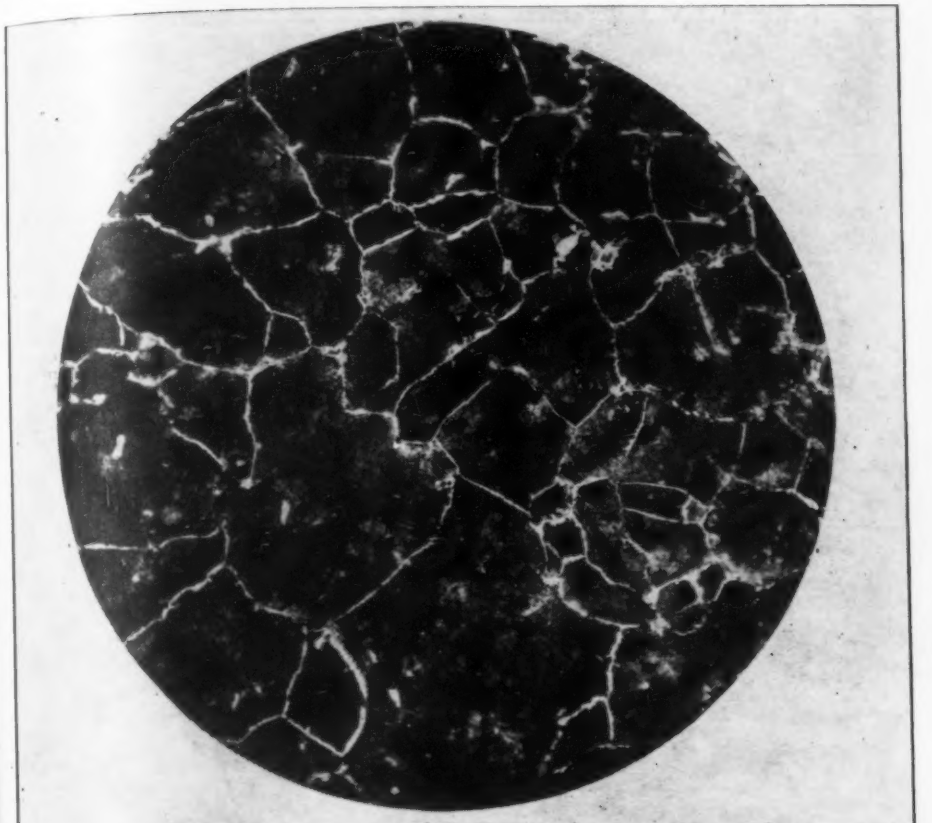
ferrite at the boundaries is the particle introduced. Hence we might reasonably expect that the further rejection of ferrite will take place at the boundaries; a part of it might join the boundaries and be located there, rendering the boundaries somewhat thicker, but another part may assume a somewhat different location, lodging itself in between the cleavage planes of the grains. The more ferrite comes out of solution the more numerous will become these ferritic bands, starting at the boundaries and running toward the interior of the grain, preserving all the time a very definite direction, parallel to the cleavage planes. Finally they will fade away, when the supply of the liberated pro-eutectoid ferrite has been exhausted.

An occurrence of this sort has been observed by the writer in almost every case when dealing with network structure in cast steels. Any photograph of network steel discussed on the previous pages can be adduced as an illustration of the occurrence of the ferrite as just described. In photomicrographs, Figs. 1, 2, 5, 7, 8 and 21, such an occurrence is well shown.

It will be recollected that the location of the ferrite at the grain boundaries is attributed to the migration of ferritic particles *toward the grain boundaries.*[7] If this were so, then we should logically expect (in the case of an incomplete process) to find the least amount of the excess ferrite in the vicinity of the boundaries: for in a case of this type the boundaries will be the goal toward which the particles move, but have not yet been able to reach. Such an observation has not been recorded by the writer.

Let us suppose now that still more favorable conditions of cooling are present. Following our line of reasoning we would expect to see ferritic bands not only branching off from the boundaries and projecting into the grains proper, but also forming the familiar cleavage structure, which would be best developed at the grain boundaries and diminish in size and perfection as the interior of the grain is approached. The series of photomicrographs, Figs. 22 to 26, are submitted as the visual representation of the described process. These five photomicrographs were taken in a straight line across a grain in 0.36 per cent carbon steel, in such a way that each following photomicrograph covers a part of the spot that was registered on the preceding photomicrograph:

[7] A theory, advanced by Colonel Belaiew, "Crystallization of Metals," London, 1922.



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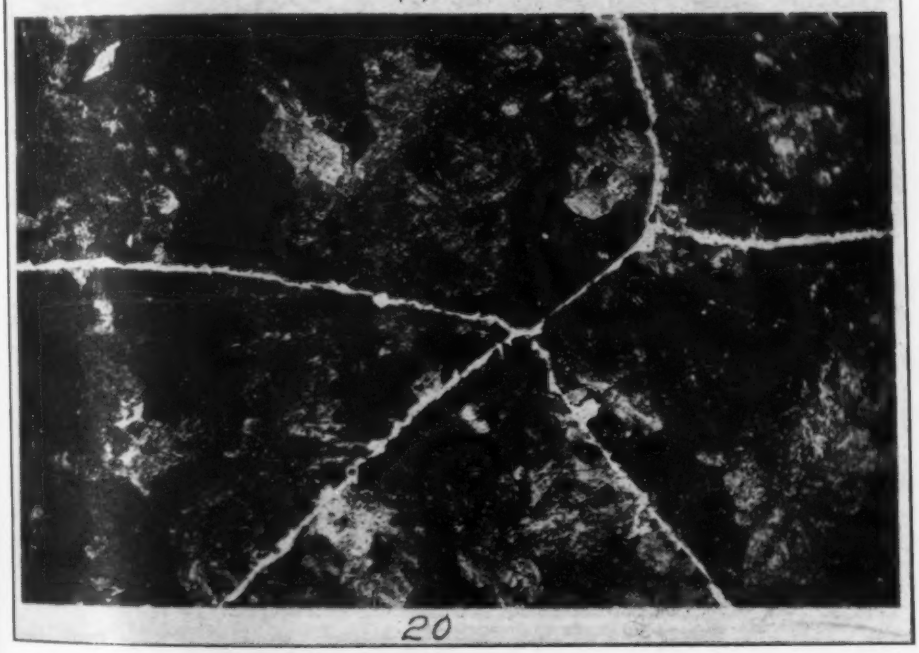

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Fig. 19—Photomicrograph of a Commercial Steel Having a Carbon Content of 0.50 Per Cent, Manganese 0.59 Per Cent. After Rapid Solidification and Cooling this Specimen Shows a typical "Net Work" Structure. 28x. Fig. 20—Photomicrograph of Specimen Similar to that Shown in Fig. 19 only Taken of another Area. 100x.

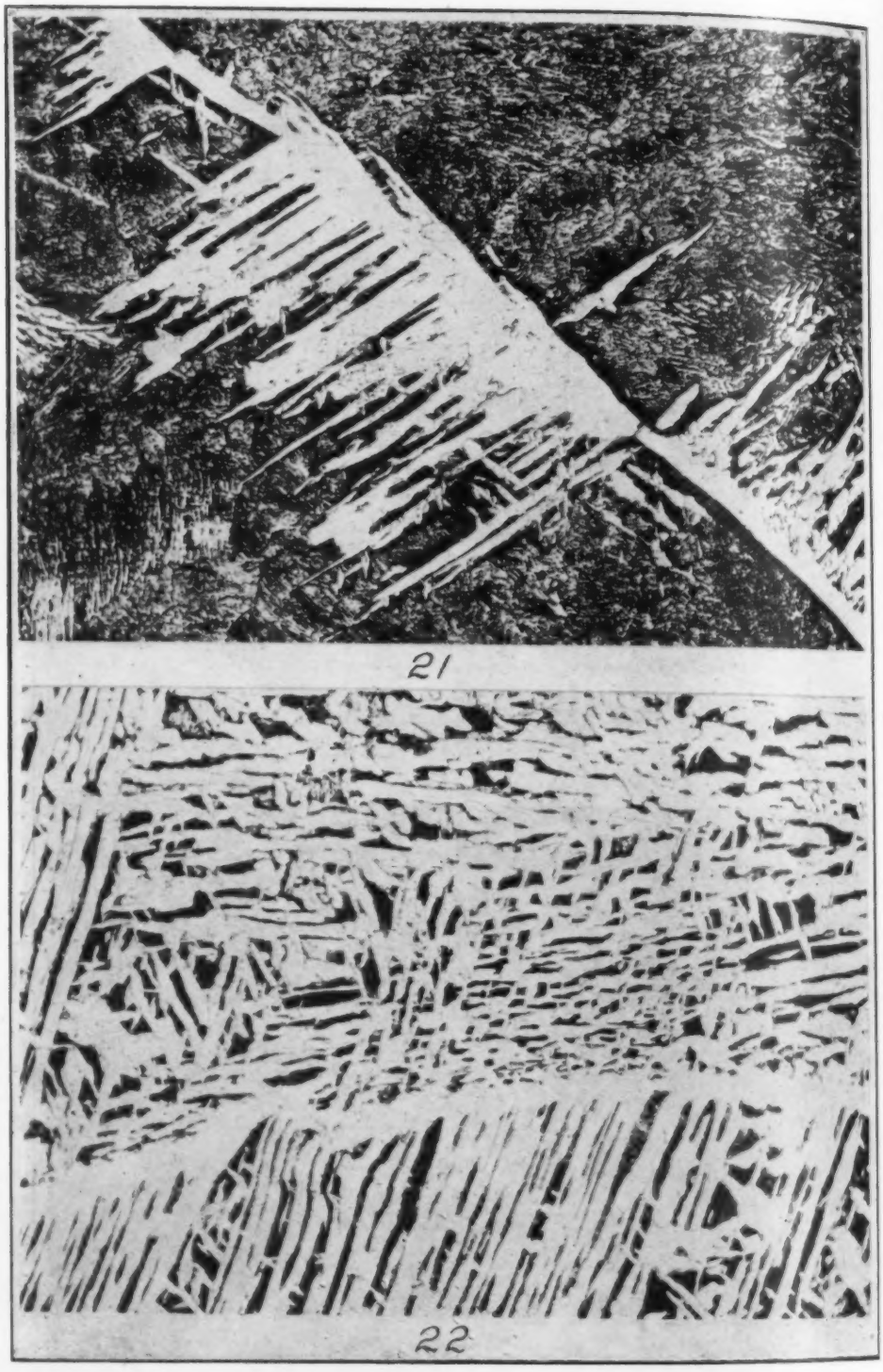
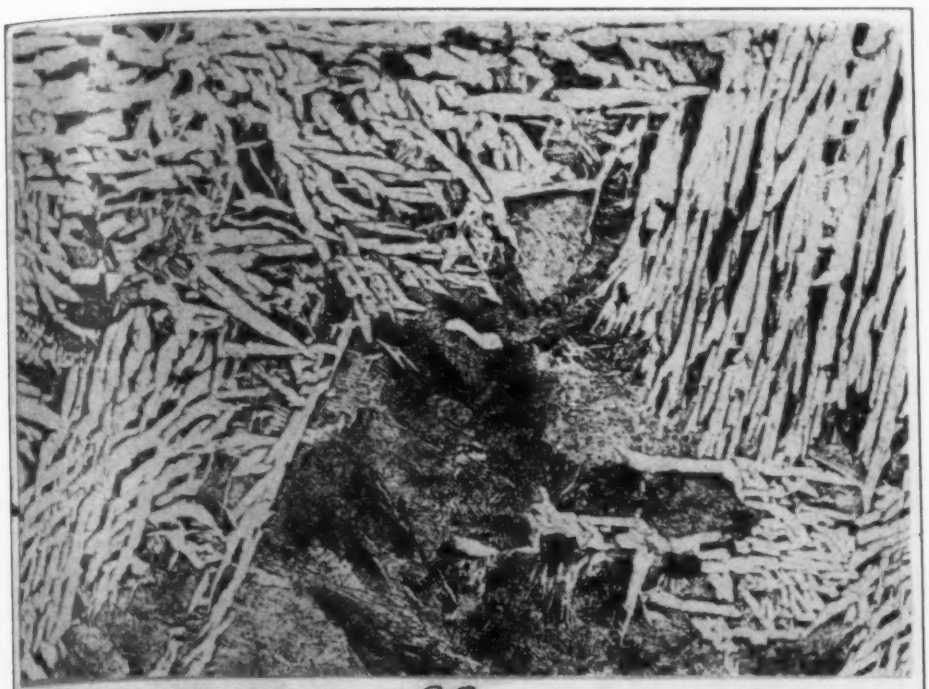


Fig. 21—Photomicrograph of Alloy M 32 Showing That the Rejection of Ferrite Begins at the Grain Boundaries. 100x. Fig. 22—Photomicrograph of an 0.36 Per Cent Carbon-Iron Alloy Showing the Boundary Between Two Grains.



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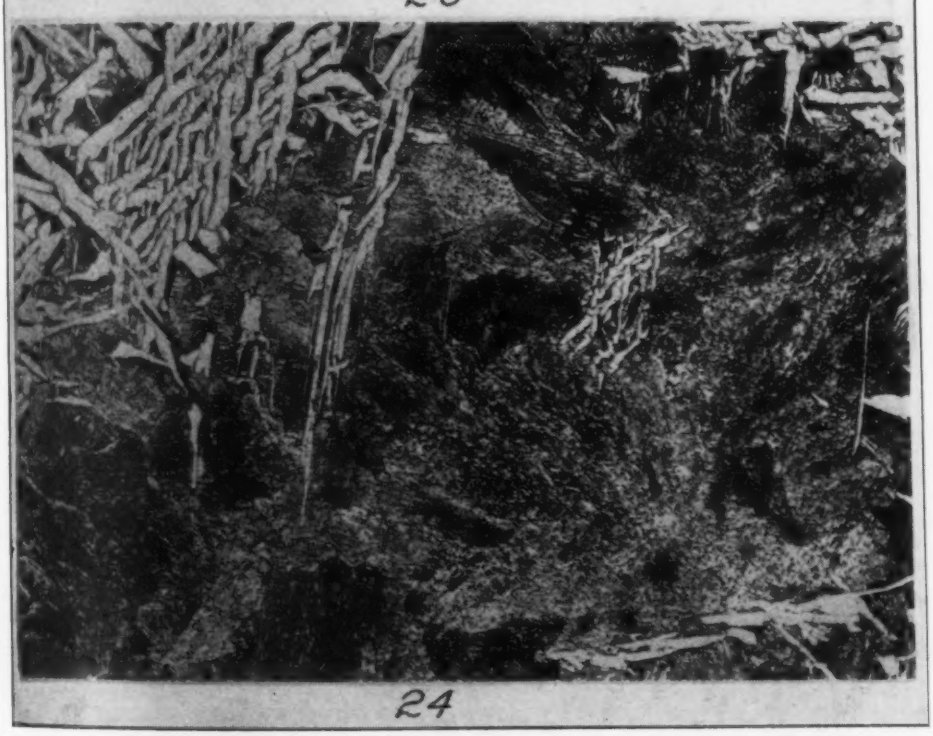

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Fig. 23—Photomicrograph of an 0.36 Per Cent Carbon-Iron Alloy Showing the Area Adjoining that Shown in Fig. 22. Fig. 24—Photomicrograph of an 0.36 Per Cent Carbon-Iron Alloy Showing Ferritic Grain Boundary Projecting into the Interior of the Grain, Which is Still Over-saturated with Ferrite and Made up of Sorbite. 100x.

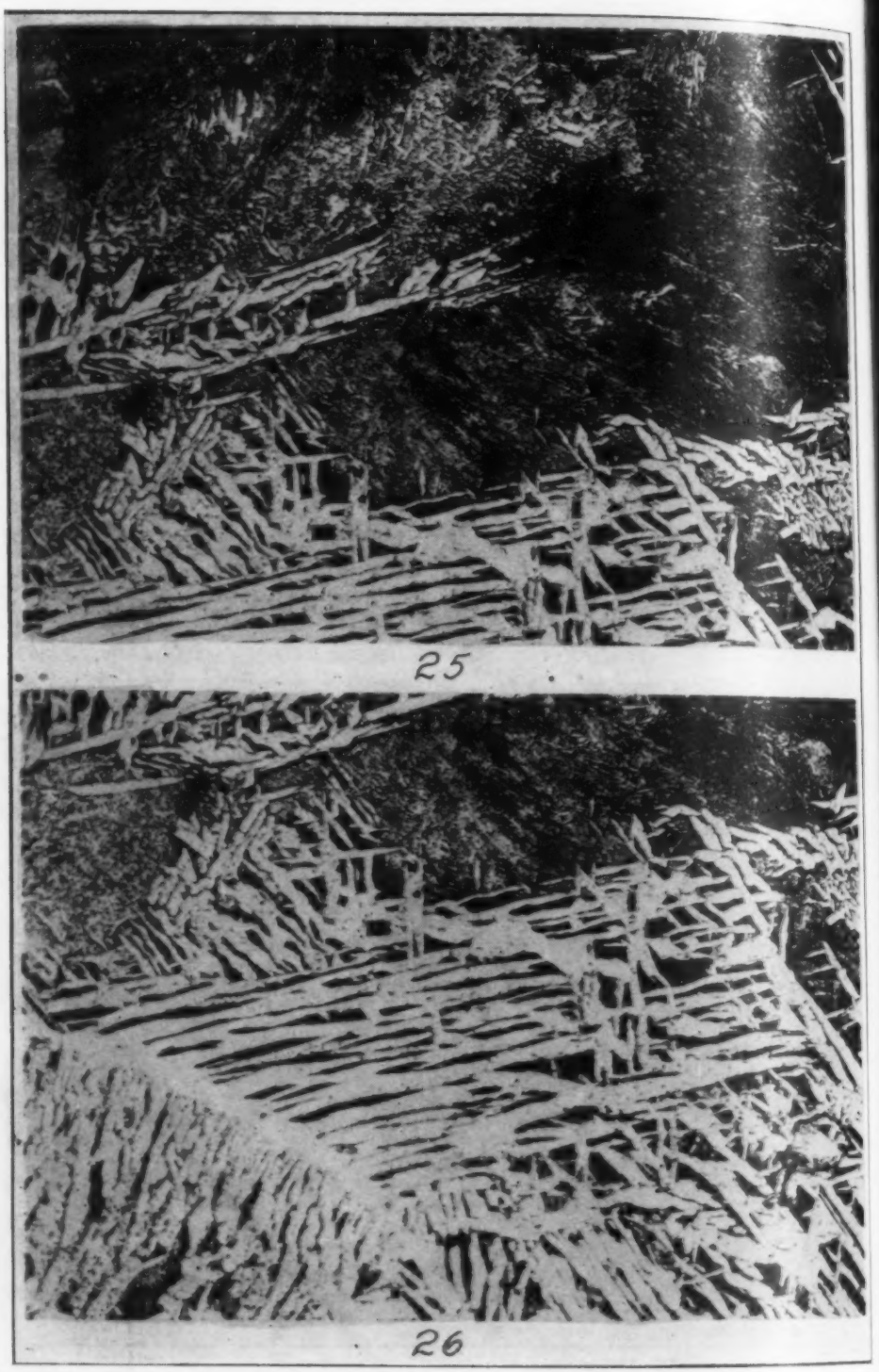
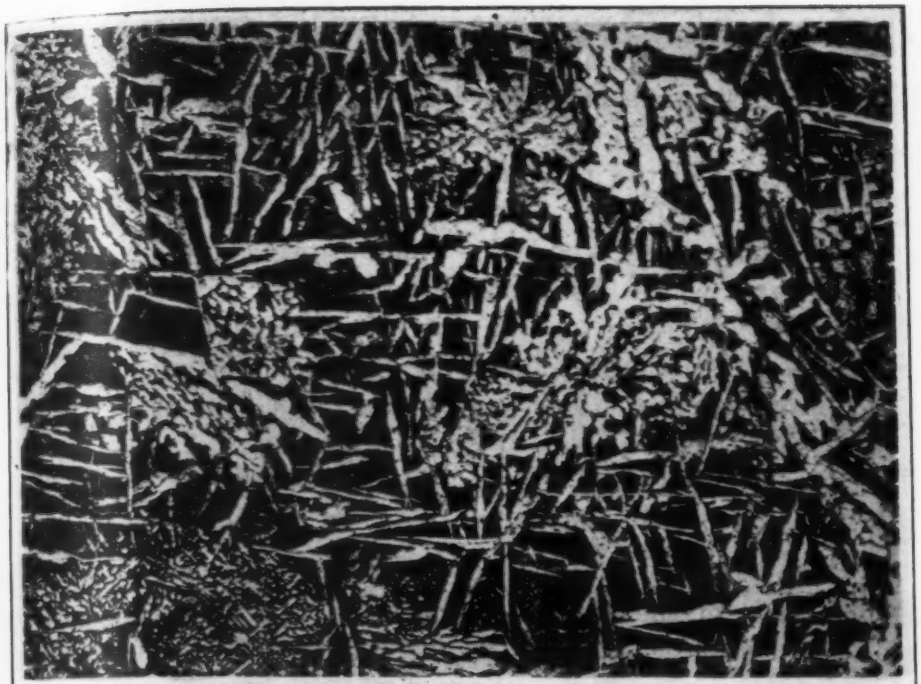


Fig. 25—Photomicrograph of an 0.36 Per Cent Carbon-Iron Alloy Showing the Sorbitic Area and Ferrite Grains Gradually Changing into Cleavage Structure. 100x. Fig. 26—Photomicrograph Showing the Cleavage Structure and Ferrite Grain Boundary that Separates the Grain Shown in Fig. 25 from the One Shown in Fig. 26.



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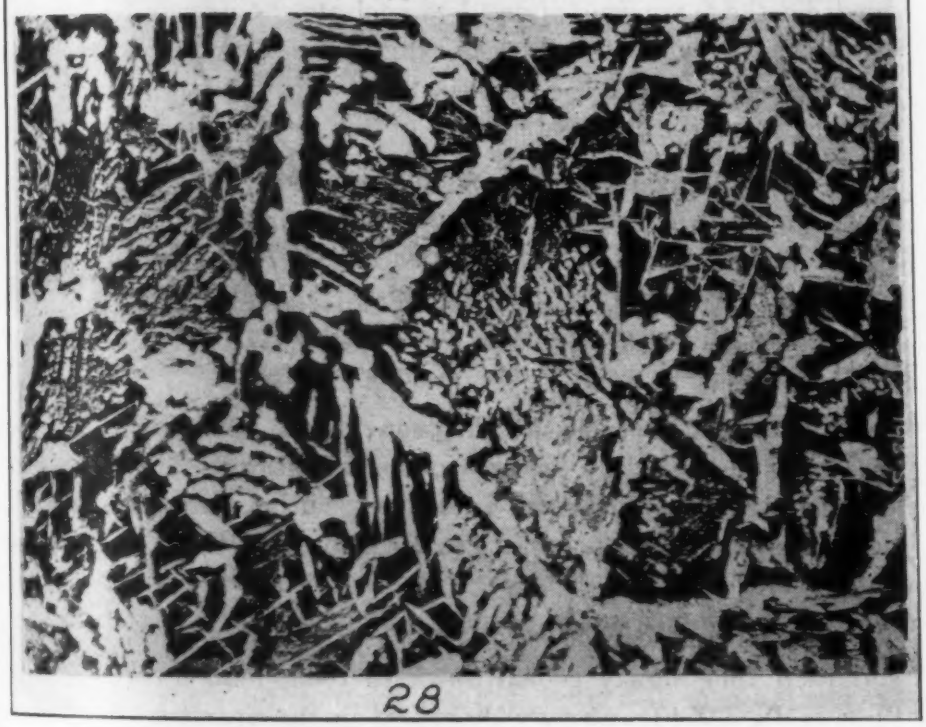

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Fig. 27—Photomicrograph of a Commercial Steel of 0.38 Per Cent Carbon and 0.60 Per Cent Manganese Made in a Resistance-Type Electric Furnace and Slowly Cooled in a Preheated Sand Mold. This Area was Taken Near the Outside of the Ingot. 100x. Fig 28—Photomicrograph of the Same specimen as Shown in Fig. 27 excepting that the Area Nearer the Inside of the Ingot was Selected. 100x.

such a procedure permits one to follow the structure of the grain from one grain boundary to the opposite. In photomicrograph Fig. 22 is shown a boundary between two grains. Fig. 23 shows a part of Fig. 22 and the spot adjoining it. It will be seen at once that the part of the grain adjacent to the boundary is made up of the cleavage structure. This structure gradually changes into separate shoots (Figs. 23 and 24), which project into the very interior of the grain which is still oversaturated with ferrite and made up of sorbite. Photomicrograph Fig. 25 again approaches the boundary,—on the opposite side of the grain, and, consequently, shows the sorbitic area and ferritic bands gradually changing into the cleavage structure. Finally photomicrograph Fig. 26 shows the cleavage structure and the ferritic grain boundary, that separates this grain from the next one.

The structure just described represents the conditions under which most of the excess ferrite has fallen out of solid solution, but the rejection, however, is not completed. It will be remembered that the rate of cooling of this alloy was artificially retarded: the ingot was allowed to cool over one hour from solidification down below the critical range. In other words, the actual conditions of cooling are in accordance with those which we should predict from the micro-structure of the steel.

Logically, if the cooling time were still more prolonged and more time given for ferritic deposition, the resulting ferritic bands would penetrate deeper and deeper into the grain until all of the excess ferrite would be driven out and lodged between the cleavage planes of the grains. So the structure of the steel would be what we call "cleavage" or "Widmanstätten."

The writer arrived at this conclusion following the line of reasoning suggested by the previous observations. The experiments which have been performed in order to either substantiate or disprove the theory, all point in the direction that the train of reasoning was correct.

Several iron-carbon alloys were made in a vacuum furnace and then very slowly cooled down to room temperature. One of these melts (M-45), already described in the previous pages, shows most complete and beautiful examples of cleavage structure (Figs. 10 and 11). Thus the experimental evidence upholds in quite a

decisive manner the theory which was built on independent theoretical considerations.

The question which has not as yet been discussed is this: is the cleavage or "Widmanstätten" structure, obtained in steels on slow cooling,—the final structure of the steel? In other words, if the cooling were still slower would not the structure change? Or putting it in still another way:—is the cleavage structure the

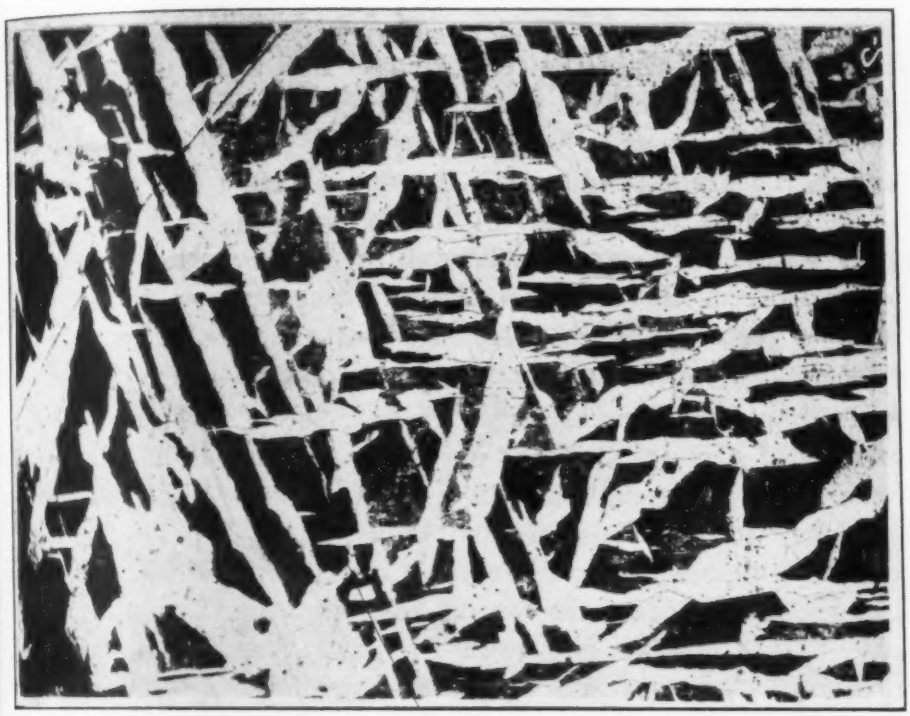

Fig. 29—Photomicrograph of an 0.45 Per Cent Carbon Steel Slowly Cooled in the Furnace. 100x.

stable phase in iron-carbon alloys? It is a difficult question to answer.

Professor Sauveur has expressed the opinion, that the structure of spheroidized cementite can be regarded as the one most approaching the stable phase. We might go one step further and regard the graphitization of the sample of an iron-carbon alloy as a condition indicative of the truly stable phase. In practice we never obtain the conditions for the production of such an ultimate phase. But undoubtedly the slower the cooling is, the more perfect cleavage structure is obtained. The particles which contain carbon become truly pearlitic. The ferritic areas may coalesce and

join each other, forming larger and thicker layers. Sometimes these layers may assume the form of a large piece of ferrite, as can be seen on part of Fig. 11. It is also conceivable that a certain part of the ferrite will join the grain boundaries: but on the whole the cleavage type of the structure will be preserved.

The writer cannot conceive the nature of the forces which would compel the ferritic islands to break from the adjoining pearlitic areas and travel toward the boundaries. If such a supposition can be entertained at all, we would not, of course, expect the actual traveling of the ferrite but some process of, let us say, interchanging. This is a theory similar to one which was widely circulated in connection with the theory of migration of particles through the grain boundaries. But even such a theory seems to the writer to be too speculative: in 0.50 per cent carbon steel if all of the ferrite is rejected, we have 40 per cent ferrite and 60 per cent pearlite as the ultimate structural composition. The writer has never seen a picture of steel in which the ferritic grain boundaries occupy ⅔ of the steel area under observation.

In photomicrographs Figs. 27 and 28 is shown the microstructure of steel (carbon 0.38 per cent; manganese 0.60 per cent; silicon 0.185 per cent) made in a resistance-type electric furnace and slowly cooled in a preheated sand mold. Fig. 27 shows the microstructure near the wall of the ingot; it is evident that not all of the ferrite had fallen out of solution. The structure of the inside of the ingot is shown in Fig. 28: the ferritic islets are much more numerous and somewhat conceal the net structure of the ingot. A part of the same melt was put back in the furnace and slowly cooled during 12 hours' duration. The steel picked up some carbon from the graphite of the furnace (carbon 0.45 per cent; manganese 0.60 per cent; silicon 0.185 per cent): its microstructure is shown in Fig. 29. This commercial steel was made, at the writer's request, at one of the steel plants: the writer was not present while the steel was being made and, consequently, feels that this sample is free from the "personal equation."

In short, on the strength of the presented experimental evidence, the writer has come to the following conclusions:[8]

1. It is presupposed that when the temperature of cast hypoeutectoid steel reaches the Ar_1 point, the residual austenite of

[8]The writer is desirous of emphasizing that he is fully prepared to modify or discard his views if further experimental evidence should warrant it.

strictly 0.90 per cent carbon content is converted into pearlite. In other words, that *all* of the proeutectoid ferrite is ejected from solid solution (austenite). But such a complete ejection hardly ever occurs in the steels cooled in the way generally accepted in the foundry practice.

2. Part of the ferrite is rejected, part of it remains in solution. The boundaries between grains seem to be the places where the rejection of ferrite is facilitated. Such ferrite forms a continuous meshwork structure, enveloping and outlining the original austenitic micrograins. The inner structure of the grain is sorbitic, containing more ferrite than is called for by pearlite.

3. Such partial rejection of ferrite occurs under the condition of rapid cooling through the granulation and secondary crystallization zones.

4. If the cooling is somewhat slower more ferrite is rejected. The ferrite at the grain boundaries will, by virtue of its presence, induce the rejection of the additional ferrite near or at the grain boundaries. This ferrite may (1) either join the ferrite at the boundaries, rendering the latter thicker, or (2) be located between the cleavage planes of the grain, forming "shoots" of excess ferrite. These "shoots" or "lamellæ" of ferrite will be projected toward the interior of the grain, gradually fading away.

5. Should the cooling be slower the rejected ferrite will assume more perfect forms and appear on polished sections of the steels as the "cleavage" or "Widmanstätten" structure. In an extreme case such a structure will occupy the whole of the grain.

6. It is believed that under conditions of very long and slow cooling the cleavage character of the structure will still be preserved. The "ultimate" structure, if we can imagine one, is pictured as approaching the cleavage structure, rather than the network.

7. By the expression "ultimate" structure, the writer means the structure that can be attained under the conditions excluding the possibility of either spheroidizing of cementite or the graphitization of the sample.

The experimental work that justified the publishing of this paper has been carried on in the laboratories of Prof. A. Sauveur at Harvard University. The writer desires to express his sincere appreciation of the interest, guidance and criticism constantly shown and rendered by Prof. Sauveur.

POLISHING OF IRON AND STEEL SPECIMENS FOR METALLOGRAPHIC EXAMINATION

By C. O. Burgess and J. R. Vilella

Abstract

The authors of this paper have made a study of the polishing of metallographic iron and steel specimens and have presented definite methods of procedure in the preparation of specimens so as to eliminate the possibility of error arising in the examination of poorly prepared specimens.

These authors have discussed in detail the technique and proper preparation of metallographic specimens.

Photomicrographs are included, showing the results of each polishing operation. A table of procedure is also incorporated.

UNFORTUNATE but inevitable it is that correct metallographic analysis must depend on the manner in which the samples for examination have been prepared. There is one treatment to which all specimens must be subjected, namely, the polishing operation. Concerning this feature of preparation it is astonishing to observe the contradictory ideas that are held by men prominent in the field of metallography. It appears opportune at this time to approach the subject as unbiasedly and scientifically as possible.

We are not without some literature on this subject, but almost no particulars are given and it appears to be dismissed in most treatises with rather broad generalizations, accompanied by some cautionary advice. These particulars, however, are the most valuable to a man in learning or improving his technique in this important phase of metallographic work.

Polishing plays a most important part and must, in general, be most carefully performed when samples are to be examined unetched. This was particularly brought out in the pursuance of some work on determining the cleanliness of a steel, when conclusions could be arrived at when the specimen was repolished, different than those drawn on the first examination. It was also found that specimens exhibited different appearances when pre-

The authors of this paper, C. O. Burgess and J. R. Vilella, are members of the research staff of the Union Carbide and Carbon Research Laboratories, Inc., Long Island City, N. Y.

pared by different operators. This, logically, could only be due to a defective or inadequate method of polishing.

Study was then directed to the determination of the best method of polishing, no matter how many times the piece was repolished, or who performed the operation. A method was finally developed, that to a large extent satisfies these conditions. An outline of the method appears later in this article.

Causes of Poor Results

The causes and the correspondingly poor results of defective polishing, which this method is designed to eliminate, are quite varied. There are certain fundamental things, such as choosing a specimen of a convenient size (½x½ inch), getting the specimen flat before beginning the polishing operation and keeping the separate wheels free from contamination from the others, that are fairly well known and do not need discussion here. The other less easily analyzed causes and results of poor polishing may be enumerated. Briefly they are: (1) holes caused by failure to completely remove scratches, etc., resulting from not keeping the specimen long enough on successive polishing wheels; (2) holes produced by knocking or breaking out nonmetallic inclusions, some causes of which are polishing with too wet a wheel when employing the fine powders or too long a polishing on the same powders; (3) rust holes or spots resulting from careless drying of the specimen after it is polished; (4) relief polish due principally to the use of too little water with the fine powders; (5) tinting of the specimen also caused by a too dry wheel; (6) dirt or powder left on the specimen due to insufficient washing. These effects and others must all be eliminated as much as possible in a successful polishing operation. The method to be given, seems to accomplish this to a greater extent than any other found.

Cause of Holes

The discovery was made, however, that in some cases, even with this method, holes sometimes appeared. By holes are meant those cavities visible under the microscope at diameters varying from 50 to 1000, in which it is impossible to focus on any material, such as slag, occupying the depressions, but are distinguishable

from actual pipes or cracks in the metal in that there is an apparent bottom or limit to their depth. Two explanations were possible for the occurrence of these cavities, i. e., either the hole had resulted from a failure of the finer polishing agents to completely eradicate a groove or scratch from a former fine or coarse polishing medium, or the hole has been produced by the polishing action removing material that actually occurred in the metal, and this removed material has left behind a cavity to mark the place it occupied.

In order to settle definitely the cause of these holes, a specimen was filed flat in a single direction. It was then put through the approved polishing operation, great care being exercised to have the polishing action of the different abrasives to be applied always in this single direction of filing. If the holes, sometimes found after our method of polishing, were due to failure to remove in all places the marks of previous coarser polishing, the resulting holes should logically be elongated in the direction of this polishing. This, however, was found not to be the case. The holes were round.

The above seems to disprove the explanation that holes are caused by residual marks from the coarser polishing. To verify this conclusion it was necessary to determine whether or not a known piece of slag might be removed in polishing. The fact that slag or nonmetallic inclusions are not firmly attached to the surrounding metal was proved by placing a piece containing slag under the microscope and attempting to push the slag out with a needlepoint. This was easily accomplished, a part of the inclusion breaking out. Next a piece of ingot iron was carefully prepared so that the slag, principally iron oxide, remained in the form of droplets. A particular field containing three of these inclusions was chosen and marked for later examination. The specimen was then repolished and as this repolishing was continued on the fine powders, one after another of these nonmetallic inclusions was polished or broken out, leaving behind a hole.

This phenomenon of the breaking or polishing out of inclusions is quite familiar to the experienced metallographist, as he is constantly coming across silicate, sulphide and oxide inclusions in steel in which ends or points or even a section of the side of the inclusion has been removed. Shallow inclusions appear to be the

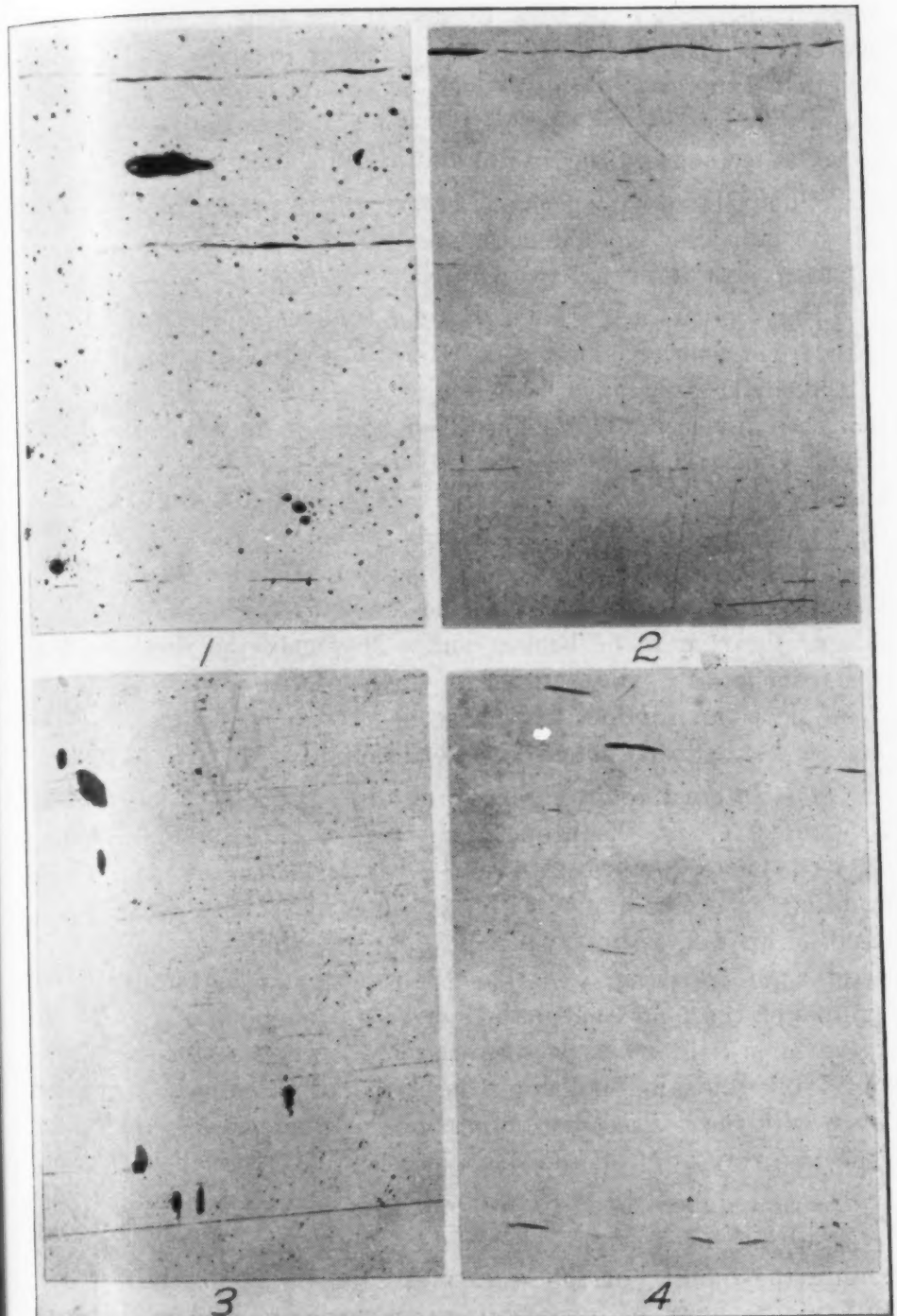

Fig. 1—Shows a Specimen that Has Been Polished by the Method Most Frequently Recommended. Holes are Observable and Portions of the Silicate Slag Have Been Removed. Fig. 2—Shows the Same Piece Polished by the Improved Method, in which the Use of Tripoli is Particularly Avoided. Here the Slag is Clearly Defined and the Holes are Practically Eliminated. Fig. 3—Shows a Specimen in which the Inclusions are in the Process of being Broken Out. From these Partially Removed Inclusions the Predominate Direction of Polishing may be Seen, Since the Tendency is for the "Leading" Side of the Slag to be Broken Out. Obviously the Direction here was from Left to Right. Fig. 4—Shows a Specimen Picked at Random from a Number Polished by the Improved Method. It is to be Noted how Clearly Defined the Slag Appears.

most vulnerable. Needless to say, if the slag is completely removed no identification of its nature is possible, and even its original extent is problematical, as when holes form they are rapidly increased in size by the continued polishing, giving an exaggerated idea of the size of the original inclusion.

Illustrations will, perhaps, be helpful in presenting the results of the polishing method recommended, and the results normally attained with the usual procedure.

Fig. 1 shows a specimen that has been polished by the method most frequently recommended. Holes are observable and portions of the silicate slag have been removed. In Fig. 2, the same piece has been polished by the improved method, in which the use of tripoli is particularly avoided. Here the slag is clearly defined and the holes are practically eliminated. Fig. 3 shows a specimen in which the inclusions are in the process of being broken out. From these partially removed inclusions the predominate direction of polishing may be seen, since the tendency is for the "leading" side of the slag to be broken out. Obviously the direction here was from left to right. In Figs. 4 and 5 will be seen two specimens picked at random from a number polished by the improved method. It is to be noted how clearly defined the slag appears.

It is interesting to observe the appearance of a specimen at different stages in the proper polishing operation. Fig. 6 represents the correct appearance of the surface of the specimen after grinding on #000 paper. Fig. 7 shows this same surface after grinding on well-worn #000 paper at right angles to the previous direction of polishing. This last represents one of the distinctive features of the polishing method to be outlined. Fig. 8 is a view of the same field after passing directly from the stage shown in Fig. 7 and finishing polishing on levigated alumina. While not shown with the desired distinctness in this photomicrograph, visual inspection reveals all of the slag particles present in their entirety.

As stated before, the effect of polishing out inclusions with the resulting holes often enlarged, leads to false conclusions concerning the quality of the section examined. It has been found that this removal of nonmetallic inclusions is seldom, if ever, accomplished on the different emery papers, but usually while polishing with tripoli, rouge or alumina. For this reason the specimen should be polished so as to have the fewest and finest

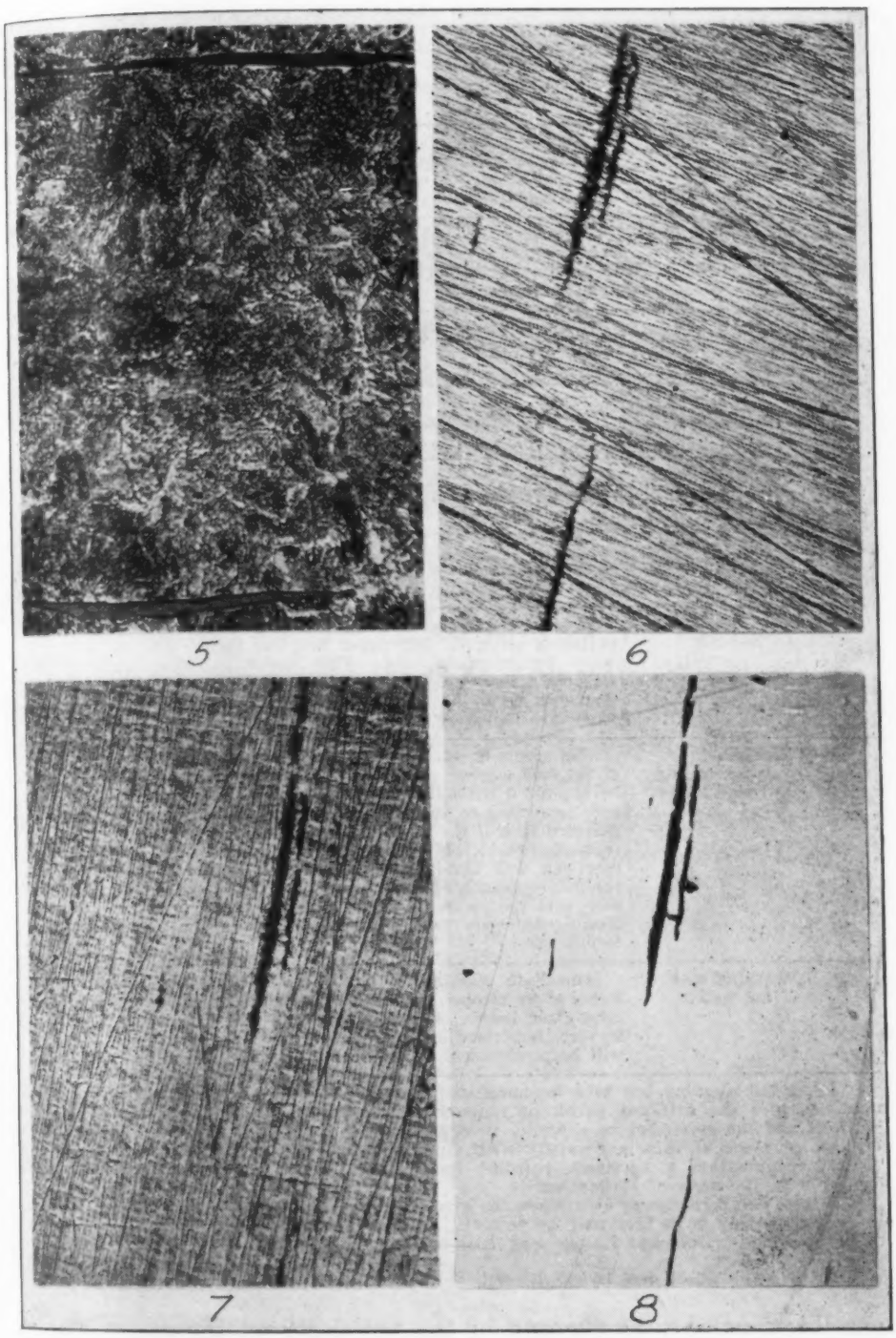

Fig. 5—Shows a Specimen Picked at Random from a Number Polished by the Improved Method. It is to be Noted how Clearly Defined the Slag Appears. It is Interesting to Observe the Appearance of a Specimen at Different Stages in the Proper Polishing Operation. Fig. 6—Represents the Correct Appearance of the Surface of the Specimen after Grinding on No. 000 Paper. Fig. 7—Shows this Same Surface after Grinding on Well-worn No. 000 Paper at Right Angles to the Previous Direction of Polishing. This Last Represents One of the Distinctive Features of the Polishing Method Described. Fig. 8—Shows a View of the Same Field after Passing Directly from the Stage Shown in Fig. 7 with Finish Polishing on Levigated Alumina. While not Shown with the Desired Distinctness in this Photomicrograph, Visual Inspection Reveals All of the Slag Particles Present in Their Entirety.

METHOD OF POLISHING

Steps	Agent Used	Notes on Technique	Relative Direction of Polishing
1	File or files*	Employ just enough pressure in pushing specimen along the corrugated face of the file to cut and not drag. A second filing on a finer file is sometimes desirable.	→
2	No. 2 Paper	Taking care not to overheat the specimen, enough pressure is employed and the specimen kept on the paper long enough to remove the file markings.	↑
3	No. 1 Paper	Kept on this paper until scratches of No. 2 paper are removed.	→
4	No. 0 Paper	Remove scratches of No. 1.	↑
5	No. 00 Paper	Remove scratches of No. 0.	→
6	No. 000 Paper	Remove scratches of No. 00.	↑
7	Well-worn No. 000	Remove scratches left by No. 000 paper by polishing on a No. 000 paper that has been well-worn by previous use. This paper produces scratches that are finer and evener than the scratches made by the best grade of No. 0000 paper available.	→
8	Levigated alumina on broadcloth	The specimen should be polished on a broadcloth with a good matte. The broadcloth should be saturated with alumina and just enough moisture employed so that the damp film seen on the polished face of the piece evaporates as it is lifted from the wheel. If enough water is not used the specimen will tarnish. The specimen should be rotated constantly, employing a gentle, even pressure, and the polishing should continue no longer than is necessary to remove the scratches of the former step.	Rotate
9	Washing with hot water	Immediate washing in hot water is advisable, followed by alcohol, in order that the drying may take place before oxidation sets in. This drying is very important, and a poorly dried specimen will be pockmarked by rust in an hour or so.	

Levigated alumina has been recommended instead of rouge for several reasons. Alumina does not give the brilliant polish of rouge but slag and nonmetallic inclusions are clearly outlined and the specimen, as a whole, is cleaner. Less surface flow also seems to take place (if the existence of this is granted) with alumina as at high magnifications and employing conical illumination a specimen polished by alumina shows minute scratches, a desirable condition in the authors' estimation.

Tripoli has been found, even when the greatest care is employed, to dig out inclusions and to exaggerate any holes that may be present. Its use is permissible when a structure alone is to be examined. Unetched its use may lead to incorrect conclusions.

*A grinding wheel may be substituted.

possible scratches at the end of the polishing on the emery papers. By this procedure the time that the specimen must be kept on the fine powders is cut down and thus the tendency to produce holes lessened.

In presenting a general outline for governing polishing, several considerations must be taken into account. It must be understood that this discussion is confined to the preparation of iron and steel specimens. Even in this field, however, we run from the relatively soft pure iron, as ingot iron, to the hardened alloy steels. This particular outline is given for a 0.40 per cent carbon steel and only slight modifications, easily determinable by the polisher, are necessary to adapt it to almost any iron or steel sample presented.

Another consideration, quite important in commercial polishing, is the element of time, and this has been given attention. It has been found that a person can take a specimen roughly cut to size, and obtain by the outlined method a perfect polish upon one face in an average time of from 15 to 20 minutes. This last estimate represents a fair average, much depending on the hardness of the piece. The above time could also be cut down by a lavish use of fresh paper on the wheels.

In the preceding outline it is assumed that the specimen has been cut to a size suitable for polishing with standard equipment. The authors have the usual polishing apparatus in mind, consisting of either horizontal or vertical wheels, on which different grades of emery paper may be placed, and additional wheels provided with cloths for the final or finishing stages of polishing.

The authors desire to acknowledge their indebtedness to D. Beregekoff of the Union Carbide and Carbon Research laboratories, whose intelligent and painstaking preparation of the samples assisted this work materially.

Educational Section

These Articles Have Been Selected Primarily For Their Educational And Informational Character As Distinguished From Reports Of Investigations And Research

THE CHEMISTRY OF IRON AND STEEL*

By F. T. Sisco

Abstract

In the basic open hearth process scrap and pig iron are melted and refined in a basic-lined furnace, using a basic slag. Silicon and manganese are oxidized and almost completely removed in melting. Carbon is oxidized by iron ore. Most of the phosphorus is oxidized and retained by the slag as tricalcium phosphate. Sulphur is partially removed. After the removal of the metalloids the metal is recarburized and deoxidized by carbon and ferro-manganese added while tapping. In the acid open hearth and acid electric process the furnace has an acid lining and an acid slag. Silicon, manganese, and carbon are oxidized and removed as in the basic process. Sulphur and phosphorus are unaffected. With an acid slag the metal may be partially deoxidized and the ferro-alloys added to the metal in the furnace. This partial deoxidation results in a steel of higher quality than basic open hearth.

The Chemistry of the Basic Open Hearth

IN the basic open hearth process a mixture of cold scrap and pig iron, either cold or molten, is melted down in a furnace having a lining of basic refractories and using a basic slag. All of the oxidizable elements, including carbon, silicon, phosphorus and manganese, are eliminated, either wholly or in part, in melting or refining. In addition, sulphur may be partly removed. After these elements have been reduced to the point desired and the temperature of metal and slag adjusted to that necessary, the heat is recarburized and tapped. Deoxidation and recarburization are ac-

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complished, sometimes in the furnace just before tapping, but usually in the ladle while tapping, or by both methods. In making up the charge of the basic open hearth process a varying mixture of scrap and pig iron is used. The amount of each may range from nearly all scrap to all pig iron, depending upon the economic conditions in that locality. Thus in the small open hearth plant where there are no blast furnaces and where scrap is cheaper than pig iron the charge may consist of 80 per cent or more scrap. In the large plant operating its own blast furnaces and furnishing the open hearth plant with molten metal the proportion of pig may be as high as 70 per cent or even 100 per cent. In average practice the amount of pig iron used ranges from 40 to 65 per cent of the charge.

The chemical reactions involved in the manufacture of basic open hearth steel are slightly different, depending upon the amount of pig iron used and whether it is added to the furnace in the solid or molten state. As it would be impossible to discuss all of these slight differences in reactions we must confine ourselves to the description of the principal reactions occurring in the process, as these are common to all variations in practice and are essentially the heart of steel-making by this process.

Chemically the basic open hearth process may be divided into five distinct steps:

1. The reduction of silicon and manganese to a minimum
2. The oxidation and removal of the phosphorus
3. The oxidation of the carbon
4. The reduction of sulphur to a minimum
5. Recarburizing and deoxidizing.

Elimination of the Silicon and Manganese

The first four reactions taking place in the basic open hearth are between the iron oxide, the silicon and the manganese, and the combining of these oxides as the slag-forming silicates.

(1) $2\,FeO + Si \rightarrow Fe + SiO_2$
(2) $FeO + Mn \rightarrow Fe + MnO$
(3) $x\,MnO + y\,SiO_2 \rightarrow (MnO)_x(SiO_2)_y$
(4) $x\,FeO + y\,SiO_2 \rightarrow (FeO)_x(SiO_2)_y$

The manganese and iron silicates immediately rise to form the slag.

These reactions occur actively during melting and are practically finished by the time the bath is completely molten.

The ferrous oxide present is the result of the oxidation of the iron by the oxygen in the hot furnace gases, or from any rust or scale on the scrap or pig iron. If molten pig iron is used iron ore or mill scale is usually charged at about the same time. The ferrous oxide, FeO, for reactions (1) and (2), then comes from the dissociation of the Fe_2O_3 or Fe_3O_4 charged.

Theoretically, silicon should be completely oxidized before the manganese is removed at all. Actually, manganese for the most part goes with the silicon in melting, although it tends to lag behind the former element. Manganese is never so completely removed as the silicon; two-thirds or more goes into the slag in melting or during the lime boil. The remaining quantity, 0.10 to 0.25 per cent, is slowly oxidized (a few points each hour, if about 0.25 per cent, and less than that if low) during the rest of the heat. The presence of considerable manganese in the bath all during the heat is beneficial for a number of reasons, therefore the melter tries to keep it as high as possible; he even charges manganese ore instead of iron ore in some cases to accomplish this result.

The silicates of manganese are among the most fusible of the slag forming silicates; therefore it is desirable to have at least 1.00 per cent manganese in the original charge. In addition, manganese has a strong affinity for sulphur and for that reason is doubly welcome. If the manganese in the charge is low the melter charges manganese ore until his first slag will have at least 10 per cent manganese oxide (manganous oxide, MnO). Due to the early oxidation of the silicon and manganese, the slag, when the charge is melted, will consist principally of ferrous oxide, manganese oxide and silica.

The limestone which was charged on the bottom of the furnace before the scrap and pig iron, is partially calcined by the time the melting is complete, but due to the mushiness of the bath has not started to rise to the top. Some carbon dioxide given off in the calcination of the limestone has, however, forced its way to the top and becoming entrapped with the slag causes it to be foamy and fluffy and to increase to several times its original volume. When this occurs, the furnaceman opens the slag hole and runs off most of the first slag into the pit.

After this first slag has been run off, the period known as "boiling on the stone" commences. The calcination of the limestone now goes on rapidly. The evolution of carbon dioxide causes a more or less violent ebullition of the molten bath. Patches of the calcined stone start to rise to join the slag. The temperature of the bath is still comparatively low. Conditions in the furnace during the two hour period of boiling on the stone are most favorable for phosphorus removal.

Oxidation and Removal of the Phosphorus

The removal of the phosphorus depends, for its completeness, on three variables: 1. an excess of oxygen; 2. a very basic slag, and 3. a low temperature. The removal of this element proceeds by the formation of phosphoric acid, ferrous phosphate and, finally, tri-calcium phosphate, reactions (5a-5d):

$$(5a)\quad 5\,FeO + 2\,Fe_3P \rightarrow P_2O_5 + 11\,Fe$$
$$(5b)\quad 3\,FeO + P_2O_5 \rightarrow (FeO)_3.P_2O_5$$
$$(5c)\quad (FeO)_3.P_2O_5 + 3\,CaO \rightarrow (CaO)_3(P_2O_5) + 3\,FeO$$

Phosphoric acid (5a), formed by the reaction between the iron phosphide and the ferrous oxide in the charge, is a very strong acid. It will immediately seize upon the most convenient base available, which of course is the ferrous oxide dissolved in the metal, to form ferrous phosphate, (5b). Ferrous phosphate is not a stable compound, it is easily dissociated and easily reduced. As soon as the ferrous phosphate reaches the slag, the calcium oxide, being a much stronger base than the ferrous oxide, replaces this compound to form tri-calcium phosphate (5c).

The phosphoric acid radical in ferrous phosphate and in tri-calcium phosphate will be at once replaced by any free silica, according to reaction (5d),

$$(5d)\quad \left\{\begin{matrix}(CaO)_3.P_2O_5\\(FeO)_3.P_2O_5\end{matrix}\right\} + SiO_2 \rightarrow \left\{\begin{matrix}(CaO)_x(SiO_2)_y\\(FeO)_x(SiO_2)_y\end{matrix}\right\} + P_2O_5$$

thus exposing the phosphoric acid to immediate reduction to phosphorus. It is because of reaction (5d) that phosphorus cannot be entirely removed so long as there is silicon in the metal and free silica in the slag. It is because of this greater stability of calcium and ferrous silicate, that phosphorus cannot be removed in an acid process by a slag high in silica. The slag must be high in bases

and all of the silica must be combined. There should be a large excess of lime, CaO, to replace the ferrous oxide in the unstable ferrous phosphate, forming the more stable tri-calcium phosphate. The temperature also greatly influences the rapid oxidation of the phosphorus. The oxidation of the phosphorus, silicon and manganese are all exothermic. The oxidation of the carbon by reaction (7) is endothermic. Therefore, below a critical temperature which in this case is about 2550 degrees Fahr., the oxidation of the silicon, manganese and phosphorus proceeds in the order named, the oxygen present after silicon and manganese are gone oxidizes the phosphorus before the carbon. Above this critical temperature sufficient external heat is supplied to oxidize the carbon in preference to the phosphorus. As the heat in the basic open hearth process is increased gradually, almost all of the phosphorus should have been removed before active oxidation of the carbon commences.

Oxidation of the Carbon

This has been partly discussed in the above paragraph where it was noted that a temperature above 2550 degrees Fahr. is essential for the active oxidation of the carbon. There is a small amount of carbon removed early in the heat, even before all of the silicon, manganese and phosphorus are oxidized. The reason for this small carbon oxidation in the early stages even when the bath is still at a low temperature is not clearly evident; it is probably caused by the free oxygen in the furnace gases, by reaction (6).

$$(6) \quad O_2 + 2\,Fe_2C \rightarrow 2\,CO + 6\,Fe$$

In the first part of the melting period the scrap and pig iron, if this latter is charged cold, are directly exposed to the flame and the oxidizing atmosphere in the furnace; later the metal is exposed to free oxygen during the boil when both metal and slag are in violent agitation. The small amount of carbon oxidation by reaction (6) would take place at comparatively low temperatures, as it, in contrast to reaction (7), is exothermic, while reaction (7) must have heat supplied in order that it will proceed in the direction indicated.

The main part, probably more than 90 per cent, of the carbon removal comes after the silicon, the bulk of the manganese, and, in good practice, most of the phosphorus have been removed. The

higher the temperature the more rapidly the carbon is oxidized to carbon monoxide by reactions (7) and (8):

$$(7)\quad FeO + Fe_3C \rightarrow 4\,Fe + CO$$
$$(8)\quad Fe_3O_4 + 4\,Fe_3C \rightarrow 15\,Fe + 4\,CO$$

The magnetic oxide, Fe_3O_4, results from the instant dissociation of any ore, Fe_2O_3, added to the furnace.

It is practically impossible to remove the carbon in the open hearth process below 0.02 per cent, and exceedingly difficult to get it below 0.05 per cent. Even when removed to a point below 0.08 or 0.10 per cent the oxidation of the bath becomes excessive and poor steel is likely to be the result. With normal practice the carbon removal is constant down to about 0.08 or 0.10 per cent. Unless special grades of very low carbon steel are made, the addition of ore is discontinued at this point to prevent overoxidation.

The removal of carbon is more easily controlled than any of the other common elements, the amount left in the steel being dependent on the practice. In making low carbon steels (0.15 per cent and under) the carbon is oxidized to a few points below the minimum required. In making high carbon steels two methods are in use; one is to "catch the carbon on the way down," tapping the furnace when about the right percentage is left in the bath; the other is to melt low in carbon and recarburize with molten pig iron.

Removal of the Sulphur

The ideal conditions for the removal of sulphur, by the formation of stable calcium sulphide and by the solution of this constituent in the slag, are not present in the basic open hearth process. One essential, a very basic slag, is present. The other essential, a reducing slag, cannot be attained, as the basic open hearth is essentially an oxidizing process. By means of a very basic slag, by means of the fluidity attained, by the use of fluorspar, and by the affinity of manganese for sulphur, the basic open hearth process can be made desulphurizing to a slight extent, the removal being close to 20 per cent on an average, sometimes up to 50 per cent when conditions are ideal. The efficiency of the basic open hearth process in removing sulphur is about midway between the acid Bessemer and acid open hearth where none is removed, and

the basic electric process, whose slag will retain up to 90 per cent of the sulphur present in the charge.

At the temperature of the metal during refining, manganese sulphide is liquid and is almost completely insoluble in molten steel. As its specific gravity is somewhat less than that of the bath it will tend to rise to the top and join the slag. The tendency to rise is partially offset by the tendency of this constituent to remain dispersed in comparatively small particles which are not so easily influenced by gravity as if they were aggregates of considerable size.

There is some question as to what becomes of the small amount of sulphur that reaches the slag. Some contend that it is held in the slag as manganese sulphide. Some maintain that it reacts with the lime, CaO, to form calcium sulphide, reaction (9):

$$(9) \quad MnS + CaO + C \rightarrow CaS + Mn + CO$$

but as carbon is necessary it is probable that this reaction does not take place, although it is possible that a little calcium sulphide might be formed at the plane of contact between metal and slag. A third possibility for some desulphurization is by reaction (10); manganese sulphide being oxidized to sulphur dioxide:

$$(10) \quad 2\,MnS + 3\,O_2 \rightarrow 2\,MnO + 2\,SO_2$$

Reaction (10) doubtless takes place under certain conditions, as the odor of sulphur dioxide is often noticeable, especially in tapping. Some metallurgists claim that calcium sulphate is formed,

$$(11) \quad MnS + 2\,O_2 + CaO \rightarrow MnO + CaSO_4$$

but calcium sulphate is easily reduced by iron; reaction (12):

$$(12) \quad CaSO_4 + 4\,Fe \rightarrow FeS + CaO + 3\,FeC$$

in which case the iron sulphide would go back into the metal. A last possibility for desulphurization is by fluorspar, reaction (13):

$$(13) \quad 2\,CaF_2 + 2\,MnS + Si \rightarrow 2\,CaS + SiF_4 + 2\,Mn$$

Reaction (13), if occurring at all, is probably accompanied by another reaction whereby the manganese is oxidized to manganese oxide and the calcium sulphide to calcium sulphate.

The whole process of desulphurization in the basic open hearth is so uncertain and is the result of so many different and sometimes

conflicting conditions that the reactions involved cannot be fixed with any degree of certainty. It is probable that all of the foregoing reactions enter into desulphurization to some extent. Fluorspar is known to aid in desulphurization. A very basic slag and one that is very fluid are also conditions necessary for desulphurization.

Opposed to the desulphurizing reactions there is always the possibility, when producer gas or fuel oil is used, of the metal absorbing sulphur from the furnace gases.

Taking everything into consideration, it may be said that desulphurization in the basic open hearth process is uncertain and unreliable. Very often as much as 35 per cent of the total sulphur in the charge will be removed consistently and without trouble for a considerable period; then suddenly and with no apparent change in practice, little or none of the element will be removed.

Reactions in Recarburizing and Deoxidizing

When a basic open hearth heat is completed and nearly ready for tapping, it will contain harmful amounts of oxides and gas. These must be removed before the metal can be teemed into ingots. In addition it is usually necessary to add some carbon and manganese so that the heat will be within the required chemical specifications. The deoxidizers used are ferromanganese and sometimes ferrosilicon. The former may also furnish the carbon for recarburization. The other recarburizers used are crushed anthracite coal, or molten pig iron. As the basic open hearth slag is sharply oxidizing right up to the moment of tap (due to some 20 per cent or more uncombined oxides, FeO + MnO) it is usually necessary to accomplish both recarburization and deoxidation in the ladle. In a few cases ferromanganese may be added to the furnace just before tap. Another exception is in the making of high grade alloy steels in the basic open hearth furnace. In this grade of material the melter cannot always judge the carbon content accurately by a fracture test, consequently he adds 10 per cent ferrosilicon to the furnace to hold the carbon constant while he is waiting for the chemical laboratory to analyze the final test. What little oxidation takes place in the final ten or twenty minutes is that of the silicon in preference to the carbon.

The deoxidizers and recarburizers are added to the ladle or to

the stream of metal as it flows down the runner into the ladle. When recarburizing with molten pig, this is brought to the furnace from a mixer and poured into the ladle as the furnace taps, or in some cases the open hearth metal is tapped into the ladle containing the molten pig.

The reactions in deoxidation are:

$$(14)\quad FeO + C \rightarrow CO + Fe$$
$$(15)\quad FeO + Mn \rightarrow MnO + Fe$$
$$(16)\quad 2\,FeO + Si \rightarrow SiO_2 + 2\,Fe$$
$$(17)\quad x\,MnO + y\,SiO_2 \rightarrow (MnO)_x(SiO_2)_y$$

Reactions (15) and (16) are the most important. The bulk of the deoxidation is accomplished by reaction (15). In some grades of open hearth steel no ferrosilicon is used at all. Its use, however, is of great benefit, as its oxide, SiO_2, tends to seek out any manganese oxide suspended in the metal, to form manganese silicate, reaction (17), which, unlike manganese oxide, is easily fusible at steel pouring temperatures. Consequently manganese silicate will tend to coalesce and join the slag readily, while the manganese oxide resulting from reaction (15) is likely to remain suspended and when cold will form a defect in the metal.

Reaction (14) is not important, although it occurs to some extent. The carbon added as recarburizer is always partly lost through this reaction.

Degasification is accomplished by manganese and silicon by reactions similar to (15) and (16); these elements acting upon dissolved carbon monoxide as well as dissolved ferrous oxide.

One of the precautions necessary in basic open hearth practice is to prevent rephosphorization during tapping. Although tricalcium phosphate is a comparatively stable compound, so far as temperature is concerned; it is easily reduced by silicon, reaction (18):

$$(18)\quad 4\,(3\,CaO.P_2O_5) + 5\,Si \rightarrow 2\,(6\,CaO.P_2O_5) + 5\,SiO_2 + 4\,P$$

The phosphorus set free immediately goes into the steel. This rephosphorization is not serious if the percentage of phosphoric acid, P_2O_5, in the slag, is less than 4 or 5; if above this amount the phosphorus reduced and going back into the steel will be 0.010 to 0.030 per cent, sometimes even more. To prevent rephosphorization it is essential to keep recarburizers and deoxidizers from contact with the slag, consequently they are usually thrown into the ladle

when the bottom is well covered with metal, early in the tapping, before any slag has left the furnace.

Basic Open Hearth Slags

The first slag of the basic open hearth process, the one formed during melting, is composed of iron and manganese silicates, free ferrous oxide, FeO, and a little lime, CaO, and magnesia, MgO; both probably present as silicates. This slag is partly run off soon after the charge is melted. As soon as the lime comes up, the manganese and ferrous oxide, combined with the silica, are replaced by calcium oxide, a more active base, to form calcium silicates of variable composition. The slag at the finish will contain 50 to 55 per cent strong bases (CaO + MgO) about 20 to 30 per cent weak bases (FeO + MnO) and 20 to 25 per cent acids (SiO_2 + P_2O_5). In addition a small amount of aluminum oxide, Al_2O_3 is invariably present.

With this composition the slag will contain mono-silicates, (one part of oxygen in the base to one part of oxygen in the acid, $(CaO)_2.SiO_2$), and bi-silicates (one part of oxygen in the base to two parts in the acid, $CaO.SiO_2$) and will be very fusible. The normal basic open hearth slag is composed principally of mono-silicates.

The melter has two conditions in mind when he adjusts his slag composition: (1) chemical composition and (2) physical condition. He aims to have at least 50 per cent of active bases present, of which the CaO should be five times the MgO. If he must use a pig iron high in silica, sufficient lime must be added to preserve the ratio of 50 to 55 per cent active bases to 20 or 25 per cent active acids. This proportion is necessary to insure complete dephosphorization. In addition the strong bacisity favors sulphur removal.

When the composition of the slag has been correctly adjusted, proper means must be taken to preserve the correct physical condition, that is, the proper fluidity must be maintained. Fluidity is essential to both phosphorus and sulphur removal. Fluidity is dependent on the composition of the silicates present, the amount of iron oxide and the amount of magnesum oxide present. Iron oxide makes the slag more fluid but on account of its oxidizing power must be kept to a minmum. Magnesium oxide makes the

slag thick and viscous. The normal slag has from five to eight per cent MgO. If some of the bottom comes up, the MgO content is increased and the slag made more viscous. Drastic means, such as the use of fluorspar, must be taken to thin it. The correct slag composition and consistency is very vital in basic open hearth practice.

The Chemistry of the Acid Open Hearth and Acid Electric Process

In the acid open hearth process a charge of steel scrap and pig iron is melted and refined in an open hearth furnace having an acid lining and using an acid slag. The acid electric process is similar to the acid open hearth in general features. Both use a lining of the same chemical character and refine with slags having the same general characteristics. The principal difference, aside from the source of heat, is that pig iron to the amount of 60 per cent or more of the charge is used in the acid open hearth while the electric process, as a rule, uses little or no pig, practically the whole charge being made up of steel scrap. Of course the heats from the acid open hearth are very much larger than from the electric furnace. Six to ten tons is the maximum acid electric furnace charge using cold scrap, while acid open hearth furnaces vary in size from 15 to 75 tons or more.

The acid process makes use of some refining reactions that are identical with the basic open hearth process. There are some reactions present in the acid open hearth process, however, that differ radically from those of basic practice. On the other hand there are refining reactions possible in the basic process that are impossible in acid practice.

Acid open hearth steel production is a comparatively small tonnage each year when compared to basic open hearth production. In fact if it were not for the acknowledged superiority of the acid open hearth steel over the basic, the process would probably not have survived. Acid electric steel goes principally into castings, for which the process is preeminently fitted.

As it is impossible to remove sulphur and phosphorus, to any extent, by means of an acid lining and acid slag, the raw materials —scrap and pig iron—must contain a smaller percentage of these two elements than is desired in the finished steel. It is here that

the acid process is at a great disadvantage. The basic process described in the previous section will remove phosphorus positively and almost completely and will partially remove sulphur. This feature of basic practice is a great economic advantage as the supply of low phosphorus scrap and pig iron such as must be used for the acid process is decidedly limited, and, in addition, is growing scarcer each year. As a result the acid open hearth process is no longer able to compete with the basic open hearth for the steels made in great tonnage, such as rails, structural, plates, shapes, etc. The acid practice is now confined to the manufacture of castings, to a few makers of high grade alloy and tool steels and to the production of steel for ordnance purposes, such as armor plate, guns and the like.

As the two impurities in the charge, sulphur and phosphorus, cannot be even partially removed they cause the furnaceman no concern, except for the assurance that they are sufficiently low in the pig iron and scrap used. Consequently the chemistry of the acid process is narrowed down to the control of the carbon, manganese and silicon.

In contrast to the basic open hearth process where oxidizing conditions are present right up to the moment of the tap, in the acid process the slag may be made very much less sharply oxidizing. The metal may thus be partly deoxidized and the ferroalloys added in the furnace instead of in the ladle. This is the great advantage of the acid open hearth. A more completely deoxidized steel can be made than is possible in basic practice. Another great advantage is the high surface tension of the acid slag. This tends to prevent emulsification of the slag and metal in tapping, and results in the steel being much cleaner than that made under a basic slag.

As has been mentioned, the chemistry of the acid electric process is essentially the same as that of the acid open hearth process. Due to the fact that, ordinarily, no pig iron is used in the acid electric furnace, the oxidizing reactions will be slightly different from acid open hearth practice, but as the fundamentals are the same they will not be discussed in detail.

Acid furnace practice may be divided into two periods; 1. melting and oxidizing and 2. deoxidizing and finishing the heat.

Reactions in Melting and Oxidizing

The reactions in the melting period are all strongly oxidizing.

The flame contains an excess of oxygen which, combined with the iron oxide or rust on the scrap, is sufficient for the complete removal of silicon and most of the manganese by the time melting is complete; reactions (1) and (2):

$$(1)\quad 2\,FeO + Si \rightarrow SiO_2 + 2\,Fe$$
$$(2)\quad FeO + Mn \rightarrow MnO + Fe$$

The manganese oxide and some iron oxide combine with the silica to form iron and manganese silicates, reactions (3) and (4):

$$(3)\quad x\,FeO + y\,SiO_2 \rightarrow (FeO)_x(SiO_2)_y$$
$$(4)\quad x\,MnO + y\,SiO_2 \rightarrow (MnO)_x(SiO_2)_y$$

It will be noted that reactions (1), (2), (3) and (4) are exactly the same as occur in the melting period in the basic practice. Reactions (3) and (4) are the slag forming reactions. The complicated silicates formed by ferrous oxide, manganese oxide and silica rise to the top as soon as formed to make the slag.

Reactions (1) and (2) do not need a high temperature for their completion, so the silicon and manganese are removed from the charge almost as soon as melting is complete.

Due to an excess of ferrous oxide, FeO, there is some oxidation of the carbon in the melting period, even though the temperature is below that necessary for the rapid removal of this element (2550 degrees Fahr.). This is also the case in basic open hearth practice.

There is not sufficient ferrous oxide present immediately after melting to facilitate the rapid oxidation of the carbon, so iron ore or roll-scale is added to remove this element to the point desired, reactions (5a-5c):

$$(5a)\quad Fe_2O_3 + 3\,C \rightarrow 2\,Fe + 3\,CO$$
$$(5b)\quad Fe_3O_4 + 4\,C \rightarrow 3\,Fe + 4\,CO$$
$$(5c)\quad FeO + C \rightarrow Fe + CO$$

The ore added in small quantities is quickly reduced by reaction (5) and the rapid evolution of the carbon monoxide causes the boil characteristic of the oreing-down period.

At the end of the ore boil the metal is free from silicon and manganese. The carbon has been reduced to the desired point, about 30 points (0.30 per cent) above the required limits. The bath contains a considerable amount of dissolved ferrous oxide, FeO, and probably some dissolved or occluded gases, principally carbon monoxide, CO, which must be removed before the metal can be called finished.

It will be noted that in the acid process no material for the slag is added, as is the case in basic practice, where limestone is charged. The acid open hearth slag is made up of manganese and ferrous oxides, together with the silica from the oxidation of silicon in the charge and some silica fluxed from the lining. The acid slag, as we shall see in a few moments, is in a state of definite equilibrium so far as ratio of acid to base is concerned. Ferrous and manganese oxides are the bases. If they are in excess, silica will be fluxed from the lining to restore the equilibrium. If silica is in excess, iron will be oxidized and will pass into the slag to make up the deficiency.

Reactions in Deoxidizing

In the first part of the deoxidation period reaction (6) predominates:

$$(6)\quad FeO + Fe_3C \rightarrow 4\,Fe + CO$$

The carbon in the bath attacks any ferrous oxide with which it comes into contact. Soon the amount of ferrous oxide becomes small and well diluted. This is shown by a lessening of the ferrous oxide in the slag. The temperature of the bath is now high (about 2900 degrees Fahr. or more). At this temperature there is a reaction between the carbon in the bath and the silica in the slag at the plane of contact, reaction (7), some of the silica is reduced to silicon, which goes into the metal:

$$(7)\quad SiO_2 + 2\,Fe_3C \rightarrow Si + 2\,CO + 6\,Fe$$

As silicon is a very strong deoxidizer and degasifier it will react with any ferrous oxide or carbon monoxide dissolved in the bath, reactions (8) and (9):

$$(8)\quad Si + 2\,FeO \rightarrow SiO_2 + 2\,Fe$$
$$(9)\quad Si + 2\,CO \rightarrow SiO_2 + 2\,C$$

There is sufficient silicon reduced from silica by reaction (7), so that considerable deoxidation is accomplished and some of the silicon (as much as 0.10 per cent) dissolves in the steel. In the acid electric process where slag temperatures around the electrodes are very high, the reduction of silica to silicon becomes very rapid, and unless the furnaceman is careful, more than is desired will be reduced and go into the metal.

While the deoxidation of the bath is going one by reactions

(6), (8) and (9), the furnaceman deoxidizes the slag. He does this by lowering the amount of ferrous oxide, which is an active oxidizing agent, by the addition of calcium oxide, CaO. He cannot add very much lime to an acid slag, as the calcium silicate formed, if more than 10 or 15 per cent, has a corrosive effect on the furnace lining. He does, however, add sufficient to have some calcium oxide present and to reduce the amount of ferrous oxide to 15 per cent or below. His final slag then will contain about 15 per cent ferrous oxide, FeO, about 10 per cent calcium oxide, CaO; about 25 per cent manganese oxide, MnO; and the rest, 50 to 55 per cent silica. The slag is fluid and because of its high surface tension forms an unbroken blanket over the metal, protecting it from the oxidizing gases and allowing deoxidation, by reactions (6), (8) and (9), to proceed.

The silicon reduction by reaction (7) is usually not sufficient to deoxidize and hold the carbon constant, so ferrosilicon is added. This excess of silicon accomplishes more deoxidation and degasification by reactions (8) and (9). The ferrosilicon is added sometime before the end of the heat. Just before the metal is tapped, or during tapping, ferromanganese is added, to give the steel the proper manganese content and to accomplish the final deoxidation. This final deoxidation proceeds according to reaction (10):

$$(10) \quad FeO + Mn \rightarrow Fe + MnO$$

The manganese oxide formed by reaction (10) will seek out any silica, SiO_2, remaining in the metal from reaction (8) and (9), to form manganese silicate, reaction (11):

$$(11) \quad MnO + SiO_2 \rightarrow MnSiO_3$$

Manganese silicate is liquid at the temperature of the metal and as its specific gravity is low, it will tend to rise to join the slag.

Comparison of the Chemistry of the Basic and Acid Open Hearth Processes

We may with advantage compare the chemical reactions of the basic with the acid open hearth processes. In both cases the manganese and silicon, together with a small amount of the carbon, are oxidized and removed very soon after melting is complete. Ferrous oxide formed by the oxidation of the solid scrap and pig iron by the furnace gases or from the oxide on rust

on the scrap is the medium by which they are oxidized. In both processes carbon is oxidized and removed as carbon monoxide by the addition of iron ore or scale to the molten bath. In the basic process this oxidation of the carbon is preceded by the oxidation of the phosphorus and its removal by means of an oxidizing atmosphere and basic slag. In the acid process no oxidation of the phosphorus occurs, as the slag is acid in character. In the basic process there is some removal of the sulphur as well. This does not occur in the acid open hearth.

In the basic process there is always a comparatively large amount of ferrous oxide in the slag, and since there is no reduction of silica to silicon, the process is oxidizing up to the time of tapping. Consequently all of the ferro-alloys and recarburizers are usually added to the ladle while tapping and not to the furnace. There are exceptions to this rule, however. Ladle deoxidation is, at best, imperfect and incomplete. In the acid open hearth a considerable amount of silica in the slag is reduced to silicon, which goes into the metal and accomplishes an appreciable amount of deoxidation while the metal is in the furnace. By reducing the amount of ferrous oxide in the slag this may be made much less oxidizing in its effect than the basic open hearth slag. By reducing the ferrous oxide in the acid slag the furnaceman is also able to reduce the amount in the bath and thus start deoxidation of the metal long before the tap. He may also add ferrosilicon to the bath, followed by ferromanganese just before the tap.

The reason for the superior properties exhibited by almost all acid open hearth steels, over the product of the basic open hearth, thus becomes evident. Deoxidation is accomplished more thoroughly and more completely in the acid furnace and more time is available for the solid reaction products to leave the steel.

Acid Open Hearth Slags

Acid open hearth slags have been discussed in part in the preceding paragraphs. In composition the acid slag is made up of bi-silicates and mono-silicates and is moderately fusible. It is composed of iron, manganese and calcium silicates of rather indefinite composition. However, it always adjusts itself to a definite ratio of acids to bases. In general the slag will contain 50 to 55 per cent acid (silica) and 45 to 50 per cent bases (FeO + MnO +

CaO). Because the ratio of acids to bases remains fixed it is possible to reduce the percentage of ferrous oxide, by substituting another base, such as lime, CaO, or by increasing the amount of manganese oxide. This feature of acid practice is not present in basic slags and is the basis for a partial deoxidation in the acid furnace, a deoxidation that cannot be accomplished in basic practice.

Another great advantage of the acid slag is its high surface tension. Unlike a slag high in lime, CaO, it does not disintegrate easily and is not so likely to break up and become emulsified with the steel in tapping, as often happens in basic practice. Because of the partial deoxidation in the furnace and because of the higher surface tension of the slag, acid open hearth steel is, very generally, freer from solid non-metallic inclusions than basic open hearth metal of like composition.

The Chemistry of the Basic Electric Process

There are two branches of basic electric furnace practice; the first may be called the cold scrap process; the second, the hot metal process. In the cold scrap process 1 to 10 tons of steel scrap is melted under an oxidizing slag which removes practically all of the silicon, most of the manganese, part of the carbon and nearly all of the phosphorus in the scrap. This oxidizing slag is removed by hand rabbling and the metal recarburized if desired. A reducing slag is then used to deoxidize the metal and remove sulphur, of which 70 to 90 per cent is removed. The ferro-alloys necessary for the grade of steel to be made may be added to the metal in the furnace. After the bath is deoxidized and all the necessary alloys are dissolved and uniformly distributed the temperature is adjusted and the heat tapped.

In the hot metal process the melting and oxidizing is carried out in another furnace, usually an open hearth, and, after the silicon, manganese, carbon and phosphorus are removed to the point desired, part of the molten metal is transferred to an electric furnace where it is deoxidized and desulphurized by means of a reducing slag. The hot metal process is used for the manufacture of electric steel in large units, from 10 to 50 tons, and produces this large tonnage with a minimum of power consumption.

The basic electric process may be divided into two periods, very distinct chemically, the oxidation period and the deoxidation

period. In the discussion of the chemistry the reactions occurring in the cold scrap process will be described. It should be remembered that chemically the hot metal process is practically the same as the cold scrap process. The only difference is that the charge is melted and oxidized in an open hearth furnace and deoxidized and desulphurized in an electric furnace.

The electric process is a comparatively recent introduction into the iron and steel industry. It has the great advantage over the Bessemer and open hearth processes in that positive deoxidation may be accomplished in the furnace instead of in the ladle and that the reaction products from the recarburizers and deoxidizers have plenty of time allowed for them to leave the metal and join the slag. The product of the basic electric process may, therefore, be made much more sound and free from oxidation defects than the product of the acid Bessemer, or acid or basic open hearth, all of which are more or less oxidizing up to the moment of tapping. In addition, the electric process is the only steel making process that will remove sulphur to very low percentages. The basic electric process has a great advantage over the crucible process in that steel of just as high quality may be made in lots up to 40 tons instead of 100 to 150 pounds.

The Oxidation Period

The oxidation period in the basic electric process needs no detailed description. The scrap is charged into the furnace together with limestone for the slag and a varying amount of iron oxide to oxidize the impurities. The silicon and manganese are removed by the time melting is complete. By controlling the temperature and having a very basic slag phosphorus may also be almost completely removed. Carbon is then oxidized to the point desired. The oxidation of the silicon, manganese, phosphorus and carbon takes place in much the same way as in basic open hearth practice.

The one essential difference in the basic open hearth and in the basic electric furnace is that in the latter no oxidizing furnace gases are present as in the open hearth. All of the oxidation must come from a solid oxide introduced with the charge or just after the bath is molten. The oxygen may be added as iron oxide in the form of iron ore, roll-scale, or as oxide or rust on the scrap; or it may be added as manganese oxide in the form of manganese ore.

It is obvious that by having no oxidizing gases present we may control oxidation closely by limiting the amount of iron oxide added during this period. By regulating the amount of oxide added to the charge and by adjusting the temperature accurately we may control the amount of carbon, manganese, chromium and phosphorus oxidized. Thus, with an excess of oxygen, practically all of the silicon, phosphorus, manganese, chromium and carbon may be removed. The carbon, manganese and chromium will be brought down to 0.10 per cent or less; all except a trace of silicon removed, and the phosphorus removed to a percentage below 0.020. By using a small amount of oxide and controlling the temperature, all of the silicon but a trace will be removed; the phosphorus if not too high will be brought below 0.020 per cent and a varying amount of carbon, manganese and chromium left in the metal. The control of oxidation is a great advantage and one which contributes largely to the superiority of electric steel.

In the oxidizing period about 20 to 30 per cent of the total sulphur is removed. This is similar to the removal of the element in the basic open hearth. Sulphur removal in the oxidation period is not important, as the element is practically eliminated in the deoxidation period.

After the charge is melted and the remaining percentage of carbon, manganese and chromium, if present, is that desired for the grade of steel to be made, the oxidizing slag is removed by hand rabbling. The operation of hand removal of the slag is confined to furnaces of small capacity; if the furnace is more than ten tons it becomes almost impossible. The first, or oxidizing, slag of the basic electric process is similar in many respects to the slag of the basic open hearth. It contains about 50 per cent calcium oxide, CaO, 5 to 15 per cent ferrous oxide, FeO, 5 to 15 per cent manganese oxide, MnO, 10 to 20 per cent silica, SiO_2, and 5 to 20 per cent magnesium oxide, MgO. From 0.20 to 4.00 per cent phosphoric acid, P_2O_5, is present. In addition, 2 to 5 per cent aluminum oxide, Al_2O_3, and a fraction of one per cent sulphur are also contained in the slag.

After the slag is removed the bare metal in the furnace may be recarburized if desired or if necessary. The favored practice is to oxidize the carbon only to a percentage so that recarburization after the oxidizing slag is removed will be unnecessary.

The Deoxidation Period

The source of heat, the electric arc, used in the manufacture of electric steel, makes it possible to keep the furnace atmosphere and the slags either oxidizing, neutral or reducing in character. This is one characteristic in which the electric process differs from all other steel-making operations, and one advantage in the production of sound, high grade steel that is held by no other. So after the oxidizing slag is removed and the bath recarburized if necessary, the deoxidizing slag is put onto the metal to deoxidize and desulphurize it. The deoxidizing slag is composed of approximately six parts of lime, one to two parts of powdered coke and one part of fluorspar. In some shops the fluorspar is partly replaced by silica sand. The lime confers a high degree of basicity on the slag and the fluorspar confers fluidity and aids in desulphurization. Part of the coke added burns to carbon monoxide and thus fills the furnace with a reducing gas. Another portion floats on the slag and reduces metallic oxides which were floating on the bare bath or which were contained in the slag-making materials. Another portion of the coke combines with lime at the high temperature of the electric arc to form calcium carbide, a deoxidizing and desulphurizing agent of great potency.

The physical changes in the slag as it changes in composition after being on the bath for a short time, are a direct indication of deoxidation and desulphurization. When the slag is first added to the furnace the silica in the lime, coke ash and fluorspar reacts with the calcium oxide to form calcium silicates. The formation of these easily melting silicates, intensified by the fluorspar, makes the slag become liquid in a very few minutes after being added to the metal. When it first liquefies it is brown or brownish green in color, due to 5 per cent or more of ferrous plus manganese oxide. As the coke lying suspended in the slag reacts with these oxides and reduces them to the respective metals, the slag becomes lighter in color, finally becoming almost pure white. This is an indication of practically complete deoxidation of the slag. At this point more coke is added to promote the carbide formation. As this occurs, the slag turns slightly grayish in color when an appreciable amount of calcium carbide is formed. After the formation of calcium carbide, the deoxidation and desulphurization proceeds steadily

and rapidly. The chemical reactions in deoxidation are:

(1) $FeO + C \rightarrow Fe + CO$
(2) $3\,FeO + CaC_2 \rightarrow 3\,Fe + CaO + 2\,CO$
(3) $MnO + C \rightarrow Mn + CO$
(4) $3\,MnO + CaC_2 \rightarrow 3\,Mn + CaO + 2\,CO$

As above noted, the deoxidation is the first of the ferrous oxide and manganese oxide in the slag. When the slag is practically free from these two oxides the deoxidation of the metal begins. This takes place in three ways: 1. By the migration of oxides from bath to slag to restore the disturbed equilibrium; 2. at the plane of contact between metal and slag and 3. through a change of contact between metal and slag after stirring.

In addition to the deoxidation accomplished by carbon and calcium carbide there is also deoxidation, and in addition degasification accomplished by ferromanganese and ferrosilicon, which are added to the molten metal during the deoxidation period. The reactions taking place when these two alloys are added are:

(5) $FeO + Mn \rightarrow Fe + MnO$
(6) $2\,FeO + Si \rightarrow 2\,Fe + SiO_2$
(7) $MnO + SiO_2 \rightarrow MnSiO_3$

The manganese silicate formed is liquid at bath temperatures and tends to immediately separate to join the slag. The principal degasifying reaction is between silicon and carbon monoxide:

(8) $2\,CO + Si \rightarrow SiO_2 + 2\,C$

Reactions (1) to (4) accomplish the bulk of the deoxidation of both bath and slag. The amount of oxide left in the metal after 30 minutes to 1 hour under a carbide slag is so small that very little ferromanganese and ferrosilicon is lost by oxidation, most of both alloys going into the steel.

It is obvious that in the basic electric process conditions are nearly ideal for a complete deoxidation of the metal. Carbon and calcium carbide accomplish most of this deoxidation, leaving only a very small amount of dissolved oxides to be acted on by ferromanganese and ferrosilicon. And in addition as the deoxidizing reactions take place in the furnace, sufficient time is available for their reaction products to leave the metal completely and thus produce a clean steel.

At the end of the deoxidizing period the final slag contains

55 to 65 per cent calcium oxide, 10 per cent or a little more magnesium oxide and 10 to 20 per cent silica, SiO_2. A small amount of aluminum oxide is present and traces of ferrous and manganese oxides. The calcium is not all present as calcium oxide. The 55 to 65 per cent of calcium as oxide is a mixture of calcium oxide, calcium silicate, calcium sulphide, calcium fluoride and calcium carbide. The final slag of the basic electric process is a heterogeneous mixture of silicates, fluorides and fluosilicates of calcium, oxides of magnesium and aluminum and calcium sulphide and carbide.

Desulphurization

The essentials for complete desulphurization are a very basic slag, a very fluid slag and a reducing slag. The deoxidizing slag in the basic electric furnace process meets all three of these requirements. The slag is very basic; containing as much as 65 or 70 per cent calcium as oxide, CaO. It may be made very fluid by means of fluorspar. It is reducing due to an excess of carbon, calcium carbide or both. There are three desulphurizing reactions:

$$\text{(9a)} \quad CaO + MnS + C \rightarrow CaS + CO + Mn$$
$$\text{(9b)} \quad 2\,CaO + 3\,MnS + CaC_2 \rightarrow 3\,CaS + 2\,CO + 3\,Mn$$
$$\text{(10)} \quad 2\,CaO + 2\,MnS + Si \rightarrow 2\,CaS + SiO_2 + 2\,Mn$$
$$\text{(11)} \quad 2\,CaF_2 + 2\,MnS + Si \rightarrow 2\,CaS + SiF_4 + 2\,Mn$$

Reaction (9) accomplishes the most of the desulphurization, in fact, almost all of the sulphur is removed through the agency of carbon or calcium carbide. Reactions (10) and (11) probably aid in desulphurization. It is certain that there is some silicon reduced from the silica in the slag by the arc, and it is also certain that reaction (11) takes place, as fluorine is very active in the deoxidation period.

After the calcium sulphide is formed it is retained by the slag up to its saturation point, which is about 4.50 per cent As the electric furnace final slag will hold in solution only about 4.50 per cent calcium sulphide it is essential that the lime, coke and fluorspar used in making the slag contain as little sulphur as possible. The saturation point of the slag for sulphur increases as the temperature, basicity and fluidity increase. Thus we see that there are five variables that affect desulphurization in the deoxidation period: 1. the amount of carbon and other reducing agents in the slag, 2. the amount of active bases, 3. the fluidity of the slag, 4. the

temperature, and 5. the amount of sulphur in the lime, coke and fluorspar.

If the amount of sulphur in the slag making materials is low, the furnaceman may, by proper regulation of the other four variables, remove up to 0.150 per cent sulphur rapidly and completely. In fact it may be said that in normal practice sulphur removal is practically automatic, and so complete that the residual sulphur in the bath when the heat is tapped will be 0.025 per cent or below.

Summary

Because the basic electric process is unique in ferrous metallurgy, we will summarize the chemistry briefly. It is unique because it is the only steel making practice that permits both oxidation and deoxidation, thus combining the efficiency of the basic open hearth process with the production of as high quality as the crucible process.

In the oxidation period the steps involved are as follows:

1. By means of oxygen introduced as iron oxide, silicon and manganese are removed by the time melting is complete; the former is totally removed, the latter may be partly controlled by controlling the amount of oxidation.

2. By means of a comparatively low temperature and a very basic slag phosphorus may be wholly removed very soon after the bath is molten.

3. A variable amount of carbon is oxidized and passes off as carbon monoxide gas. By regulating the amount of oxidation the amount removed may be controlled and from 0.06 to 1.00 per cent or more left in the bath when the oxidizing slag is removed. The amount oxidized depends upon the precentage in the charge and the amount of oxide used.

4. A small amount of sulphur (about 20 per cent) is oxidized and removed in this period.

5. Chromium, if present, may be controlled in much the same way as manganese. Nickel, of course, is unaffected.

Thus we see, that by controlling the amount of oxide added to the charge and by regulating the temperature we may melt with complete oxidation, with partial oxidation or with practically no oxidation at all.

The above summary of oxidation applies only to the cold scrap process. In the hot metal process the oxidation period is absent; the oxidizing reactions occur in the open hearth furnace.

In the deoxidation period the steps involved are:

1. Through the agency of carbon or calcium carbide, especially the latter, all of the easily reducible oxides, including ferrous and manganese oxide in the slag, are reduced to their respective metals.

2. As soon as the slag is free from oxides the deoxidation of the bath commences. This takes place by migration of ferrous and manganese oxide from bath to metal to restore the disturbed equilibrium, at the plane of contact between slag and metal or through a change in this plane of contact due to stirring.

3. By means of a very basic slag, a very fluid slag, and the reducing powers of carbon or calcium carbide 70 to 90 per cent or more of the sulphur in the metal is removed and held in the slag as calcium sulphide.

4. Deoxidation is assisted and degasification accomplished by the addition of ferromanganese and ferrosilicon in the metal during this period.

5. Because deoxidation is going on steadily all during the deoxidation period, which lasts about 2 hours, the reaction products formed have time available for them to leave the metal and join the slag.

The result of the above five steps is a metal, at the moment of tap, thoroughly deoxidized, completely desulphurized and practically free from dissolved or suspended inclusions. This is the reason for the superior quality of most basic electric steel.

(*To Be Continued in May* TRANSACTIONS)

PYROMETRY

By H. A. Schwartz

Abstract

This paper touches upon the many phases of the problem of measuring temperatures which are considerably above room temperature. The author has outlined briefly the developments of the art of pyrometry and has discussed in some detail the various methods of determining temperatures. He has described the radiation type, the thermocouple type and the optical type of pyrometers.

THIS is really a talk on the theory and practice of high temperature measurements, although it is quite likely that we shall diverge from that formal statement.

It is obvious from the fact that you are having a course in heat treating that one of the fundamentals is that you should have some means of measuring temperature which is sufficiently reliable to permit of duplication of metallurgical results. Temperature measurements are rather odd things as compared with some of the more fundamental quantities with which the metallurgist may have to deal. This arises in part from the physiological limitations of the human being. We only have a general knowledge of whether a thing is hot or cold and even then we do not have this knowledge very well. With liquid air and molten tin, whose temperatures are about equally removed from that of the room, you cannot tell by feeling of them which is hot and which is cold. The sensation would be exactly alike. There used to be a very common experiment in some psychological laboratories where you put one hand in ice water and the other in hot water, then both in water of medium temperature. One hand reports the water in which both are immersed as hot; the other as cold. We can tell something about the length of an object on the basis of our senses. We can tell the length of a short stick in comparison with a longer stick. But

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A paper by H. A. Schwartz, manager of research, National Malleable and Steel Castings Company, Cleveland. This paper is based on a stenographic report of a semi-popular lecture before the Cleveland chapter's night course given under the direction of Professor H. M. Boylston of Case School of Applied Science.

we cannot take a high temperature and compare it with a low one by the same method.

Mankind has measured the fundamental things like length, and to some extent time, for around 7000 years, and it has only been 200 years since anybody measured temperatures with anything that even bordered on being precise.

We can conceive of length as an abstract concept. Temperature has to be the temperature of something. That arises from the fact that temperature is the result of molecular vibration. Consequently a perfect vacuum does not have temperature. We measure temperature always by the effect of temperature on some physical substance.

The very early step was the development of the thermometer 200 years ago, and what is really measured is the differential expansion between the liquid mercury and the solid glass. From that system of thermometry there arose the temperature scales now in use. Fahrenheit decided that the coldest thing he had ever found was an ice-salt mixture. The temperature of this mixture he called zero degrees. He then selected the boiling point of water, which was a definite thing, and assigned to it the temperature of 212 degrees. The difference between the freezing point and the boiling point was 180 degrees. The Centigrade scale runs from zero at the freezing point of water to 100 degrees at its boiling point; Reamur's from 0 to 80 degrees. It is quite a problem to discuss how you can build on a temperature scale in degrees Centigrade from 100 degrees to say 1500 degrees, the melting point of pure iron, and know that your steps are even lengths.

At high temperatures, you can look at an object and estimate the color of light that it emits and, depending on how good a guesser you are, form a somewhat good judgment regarding the temperature of the object.

Expansion and the estimation of color are still practiced as actual means of measuring temperature, and we will come as we go along to the refinements that have been introduced into these things in order to make them at all workable.

With thermometers we have to stop when the internal liquid boils or when the glass casing becomes soft.

We can help the expansion method a little bit by measuring the expansion of a gas. This, however, is not a very convenient

way for a steel treater to measure temperatures. When we remember the fundamental laws (Boyle's law), that the product of the pressure and the volume of the gas is a constant multiplied by its temperature, all that we have to do is to measure two of these quantities and compute the third one. We can measure the temperature required to keep the gas a constant volume and use that as a measure of the ultimate temperature.

The expansion pyrometer was for a time a real commercially usable thing. It has a lot of undesirable features. It cannot be used in the furnace for a very long period and cannot be extended very far into the furnace. It measures the temperature over a rather large area because the platinum strip whose expansion measures the temperature is six or eight inches long.

Another little scheme used in determining temperature was to put a small body, preferably platinum, into the furnace and then jerk it out quickly and throw it in water and measure the rise of temperature in the water and calculate the temperature of the platinum when it went into the water. If this scheme is carried out carefully, good results may be obtained. In its time, this method was one of the useful methods of temperature measurement.

Nowadays, however, pyrometry means the use of a thermocouple for temperatures that are within the range of thermocouple measurement. A thermocouple consists of a pair of wires of two dissimilar metals which are fused together into a little bead and that little bead is placed at the point where it is desired to measure the temperature. The ends of the wires extend out of the furnace and connect with an instrument for measuring the electromotive force. When the junction of two dissimilar metals is heated, an electrical potential is set up. There is a direct relation in any given pair of wires between the magnitude of this electromotive force and the temperature to which the juncture of the two wires is heated. Many different kinds of wires can be used depending upon the particular circumstances. Each kind of wire has certain characteristics to recommend it and certain ones to hinder it. If it is desired to work with rather low temperatures, antimony and bismuth are rather advantageous for one of the wires. Their melting point is not high enough to be useful for steel treating. Alloys of nickel and chromium and the alloys containing aluminum and the combinations of some of those with iron

may be used. There are a vast number of possibilities of relatively cheap metals which will make very nice thermocouples. The ones that have just been mentioned are in the class of base metal couples and have the disadvantage that their melting points are relatively low. They are the alloys of two different elements and usually the melting point of an alloy is lower than that of the constituent elements. They are more likely to be affected by the chemical reactions; primarily oxidation. They have the great advantage that they set up rather large potentials for a given temperature. While they are cheaper than other couples, the greatest advantage is their sensitivity.

If we have to consider permanence, both in the sense of the equipment not wearing out and in the sense of the calibration being constant, ahead of the price and sensitivity, then the almost universal combination is that of platinum and platinum-rhodium. These noble metal wires, platinum and platinum-rhodium, have the disadvantage of high cost. They have the advantage that they hold their calibration. The electromotive force is always exactly the same at the same temperature. In scientific work usually the platinum and platinum-rhodium couple is the ultimate standard of comparison. Irrespective of the kind of wire used, we assume that the electromotive force corresponding to a given temperature is known, and the question of how we shall measure temperature becomes a question of how we shall measure this electromotive force. Here we enter into the realm of electricity, always staying in the science of physics.

The simplest way to measure electromotive force is to connect a millivoltmeter or galvanometer to the couple. A galvanometer consists of a permanent magnet and a coil of wire so arranged that one can move with respect to the other. Generally the permanent magnet is a horseshoe magnet with the coil of wire mounted so that it may rotate between the poles of that magnet. If an electric current is sent through the coil the coil rotates until the torque of the electric current balances the torque of the filament or hair spring used as a control for the portion of the coil.

All of these instruments depend for their action not on the electromotive force but on the current which flows through them. We can derive the current from the electromotive force by the law

that the current is the electromotive force divided by the resistance:

$$I = \frac{E}{R}$$

Evidently if we have an instrument which measures electric current and we desire to use it to measure electromotive force we must carry over into the calibration of the instrument some conception regarding the resistance that this whole circuit is to have. This can be done in quite a number of different ways. If we vary the resistance appreciably we vary the indication of the apparatus and therefore introduce an error into our temperature measurements. Some systems when installed have the resistance of the whole circuit of the thermocouple and of the measuring device and of the leads permanently adjusted to a constant value. Another system is to make the resistance of the measuring instrument very high and then if the resistance of the thermocouple and of the leads is not always the same it is a small proportion of the total resistance and it affects the results only to a small degree. Both of these methods prove workable. It is a matter of expediency. The high-resistance type requires a sensitive galvanometer. High resistance means a small current flowing, hence delicate apparatus, so that a small current will produce a visible deflection of the needle. Another error enters. Whenever a galvanometer is used it must be borne in mind that with copper there is a change in resistance when the temperature changes. If the instrument is near the freezing point at one time and then in a hot room at another time the resistance is higher the second time than the first. The current flowing for a given electromotive force is less and will read too low in voltage. In the high-resistance type instrument this difficulty can be overcome by making the windings out of some alloy wire whose resistance changes only minutely with the temperature, or the measuring instrument can be kept in a constant temperature room. With the low-resistance type much of the resistance is in the leads and cannot be kept constant. One of the difficulties with all millivoltmeter pyrometric systems is this change of resistance with the change of temperature.

There are sometimes occasions when we not only want to read the temperature but also want to record it mechanically. One of these indicating types of instruments is provided with some means

by which the motion of the pointer can be recorded on a chart that is operated by a clock-work mechanism. There are various mechanical modifications for doing this. It is a simple matter to make one of these deflection instruments into a recorder. All you have to do is move a paper at a constant rate under the point of the indicator and have the point carry a pen to draw its curve.

In the Harrison-Foote circuit, corrections are made for changes of resistance in the couple and in the leads joining the couple to the galvanometer. This is one of the pyrometers which is on the market, and when it is in good operating condition it works very nicely. The principle is that a circuit can be so arranged that a resistance in series with the thermocouple can be adjusted until the galvanometer gives the same deflection when the current is passed through either of two sets of resistance coils in circuit with it. It is a fact that when the rheostat is adjusted so that there is no change of deflection whether the switch key controlling the path of the current is in or out, then the resistance of the external circuit is of a certain fixed value for which the indicator is calibrated.

There is another means of measuring electromotive force which measures it directly without the intervention of any relation between electromotive force and current. If we have a wire at whose ends a fixed electromotive force is maintained by a battery then there is a uniform fall of potential through this wire. If we have a thermocouple connected through a galvanometer to one point on this wire and at the other end to a slider traveling on the wire, then we can move the latter to and fro until there is no flow of current through the galvanometer. The fall of potential due to the thermocouple in one direction balances the fall of potential due to the battery, and no current flows. This galvanometer does not have to be calibrated; it is merely an indicator of the fact that there is no current flowing. If we know the total electromotive force of the battery and the total resistance of the wire, we can pro rate the electromotive force of this battery and measure the applied electromotive force directly. This is called the potentiometer method. It has the disadvantage that it requires a manual operation to determine the point when the millivoltages balance. Its advantages are that it does not make any difference what the resistances of any of the connections in this circuit may be; all we need to

know is the resistance of the potentiometer wire, and that stays nearly at constant temperature always. There are, however, automatic potentiometers.

A potentiometer can be converted over into a recorder. We can devise automatic means for moving the pointer to and fro continuously, so that it always keeps with the position of no-current in the galvanometer and then move a strip of paper at constant rate under a pen fixed to the slider. We can plot temperature against time and record it very nicely. An apparent defect is that we have a lot of machinery and when we look at the thing we wonder how it runs. It will keep running almost indefinitely. It is not a thing that is as hard to maintain as one might think, although it is a complex piece of apparatus.

We must remember in any one of these thermocouple schemes of measuring, that the thermocouple measures the temperature difference between its hot end and its cold end. Its cold end is the point where the two dissimilar metals join the copper wire which forms the leads or the windings of the instrument. Suppose at 70 degrees Fahr. we have a thermocouple which reads 1500 degrees Fahr. Considering no cold-end correction it means that there is a 1500-degree difference of temperature between the hot and the cold ends. We know that the cold end is 70 degrees, so that the temperature in the furnace is 1570 degrees Fahr. If the temperature of the room becomes 100 degrees and the reading remains unaltered, the temperature inside the furnace has become 1600 degrees Fahr. If the reading remains the same the furnace temperature has risen 30 degrees. That means that we have to devise some means by which we can correct for these variations. One of the old and simple ones was to run the point where the copper wire is joined on to the couple wires underground four or five feet where the temperature of the earth remains constant. Then the cold temperature is the temperature of the earth in that location.

With a water jacket, if the water supply is from a deep well, we may have a temperature which for most purposes is sufficiently constant. Another scheme is to put the cold end in a box and put an electric light bulb in the box, and provide a thermostat which will keep a constant temperature higher than room temperature and which switches the current on and off to maintain constant temperature.

These schemes all involve maintenance of some kind of cold end temperature. Another type of correction which does not involve the keeping of the cold end temperature constant involves an electrical correction for the changes of temperature. Suppose we connect the wire from the galvanometer to another slider instead of attaching it permanently to the potentiometer circuit in a given spot. If we move this second slider by an amount corresponding to variations in room temperature, then the position of the first slider will not require changing unless the temperature within the furnace changes. This principle is used in potentiometers and potentiometer recorders.

An automatic means of doing this electrically is also available. In this we have shunted across the potentiometer wire two wires in series, one having a high thermal coefficient of resistance and one a negligible coefficient. One terminal of the thermocouple circuit is connected to the junction of the dissimilar wires. It is possible to make the ratio of the resistances and of the coefficients of the resistance right, so that by this hook-up the correction for cold end temperature is automatically made. The electrical resistance becomes proportionally greater on one side of the point of contact with the external circuit than the other, due to differences in temperature by just the amount to shift the electrical position of the contact in proportion to changes in room temperature. It is a very simply operated thing.

There is still another method by which temperatures are measured electrically. All through this talk we have laid a lot of stress on the change of resistance of leads, apparatus, etc., as the temperature changes. Change of resistance is a very good way of measuring temperature. We can make a coil of platinum or copper; the one requirement is that the metal shall be permanent at the temperature at which it is to be used. We can measure that resistance and from the resistance we can determine the temperature of the coil. The measurement of the resistance can be made very accurately without electrical complexities as to the relation between electromotive force, resistance and current flowing. It is one of the most precise things in the realm of physical measurements. Such thermometers are not used very often because the resistance thermometer coil is a good deal greater in size than a thermocouple. It is a little harder to put in a furnace and costs

a good deal of money. Resistances are measured by an apparatus called a Wheatstone bridge resembling in principle a potentiometer.

These methods which we have been discussing have implied that we can put part of our apparatus into the furnace and heat it to the temperature at which we are working and that is all right for all strictly heat treating operations that come along. The melting point of platinum or platinum-rhodium is sufficiently high, so that the temperatures which we have to use for the hardening of steels, etc., will not melt them. Sometimes we have to measure the melting points of metals like iron. That is still within the range of the platinum-rhodium pyrometer. We might want to measure the temperature in an electric arc furnace wherein the temperature goes way beyond the ability of any metal to survive. In that case there are two or three schemes to use.

The radiation pyrometer again depends on a thermocouple. It looks like a shotgun barrel. We aim it at a point in the furnace that has the temperature we want to measure. The furnace opening must be large enough so that its image fills the whole diaphragm at the "muzzle" of the barrel. The heat rays come down the tube and strike a conical mirror and by multiple reflection come down and heat a thermocouple. They heat it a definite proportion of the temperature of the furnace. You can alter the sensitivity by having different sized diaphragms. A small diaphragm means high temperature of the furnace for a given reading. This is one of the schemes by which the temperature of the blast furnace is measured.

Looking into the furnace and seeing the color is an old method which has been refined into the optical pyrometer. The hot body has its image focused on the filament of an incandescent lamp by a lens. Usually for high temperatures there is an intervening screen which cuts out some of the light. The screen is a sort of reddish color. We look into an eyepiece at one end and adjust by a rheostat the current through the filament until the filament is neither darker nor lighter than the image of the object we are looking at. Read the current flowing through the lamp and look on the calibration curve to see what the temperature is. This is one of the very neat means for measuring temperatures which are so high that we cannot heat any object thereto and have it perma-

nent enough in properties to measure. The filament is not as hot as the original object because we have filtered out a definite amount of the colored light. The filament is tungsten and in a vacuum, so that it is somewhat permanent. When it gets old it gets out of calibration and it is a relatively expensive job to have a new calibration made.

In another construction in which we have an optical method of temperature measurement we compare by looking through an eyepiece, the light coming in one direction, from the furnace, with light from a filament coming in another direction. Images of the filament and object are superimposed on each other. We put a wedge of colored glass between the object and the image and insert the wedge until the colors balance. The advantage is that in this apparatus the filament is not calibrated at a lot of temperatures. All we have to know is what current will burn it at a standard degree of brightness. Screw a new lamp in and set for a different current which is known to give the standard brightness for the replacement lamp.

There are just a few items left. For either of these radiation types we have to make allowance for the fact that the heat or the light emitted by a body is not altogether a function of its temperature. If an object is entirely within an enclosure and the temperature of the enclosure and the object is the same, we call it a black body condition. If we take that body out and set it down in the air, the amount of radiation for the same temperature decreases. In the case of light change, this is called emissivity, and in the case of heat, it is called coefficient of radiation. These coefficients are different for different materials, and we have to consider what is the emissivity or the coffiecient of radiation when we use either of these radiation types of pyrometers.

The last few points which I desire to talk about are some of the practical things that are to be considered in actually measuring the temperatures in a furnace which in general is not uniform. A thermocouple of course does not measure the temperature any place except where it is and consequently we must take care that we locate the thermocouple in a place where we want to measure the temperature. Locate the thermocouple actually in the place whose temperature we want and do not assume that another place is necessarily of the same temperature.

Ordinarily thermocouples have to be protected from the furnace atmosphere. Platinum, platinum-rhodium thermocouples should not be immersed in carbon monoxide. Consequently, even the noble metal couples have to be enclosed in suitable varieties of refractories or in metallic sheaths that can be replaced in order to protect them from contaminating influences. This is still more true of base metal couples. Unless we know what the atmosphere is going to be we must use a protective armor. Sometimes we put armor on to protect them mechanically. If we use armor it must be remembered that it takes time for heat to travel into the couple and quite considerable time. We cannot insert a thermocouple in a furnace and wait thirty seconds and expect to get exact or accurate readings. Usually we get an extremely low reading. Thermal lag of the couple is of quite a little importance where quick changes of temperature are to be measured. Also the center of a large piece of metal, or container full of small parts, is much slower in coming up to temperature than the surface. To assure that the temperature within is at the required point, either the thermocouple must be at the center of the piece or else we must know the lag of the temperature at the center behind that at the surface.

Such considerations seem self-evident but are occasionally overlooked.

NOTES FROM THE U. S. BUREAU OF STANDARDS

International Cooperation in Metallurgical Research

THE question of the effect of gases in metals, especially in steel, has been under investigation at the Bureau of Standards for a number of years and progress has been made in the development of methods for the determination of the amount of gases and gas-forming elements present.

Swedish metallurgists have been interested in the same problem, especially in their search for some test to show the presence or absence of the property called "body" which is supposed to account for the alleged superiority of Swedish steel. Dr. Bengt Kjerrman of the Ingeniors Vetenskaps Akademien, Stockholm, has studied the "gas-in-steel" problem and has devised methods for the work.

In order to compare the methods used in Sweden and those used at the Bureau of Standards, Dr. Kjerrman has been sent to America for a year.

As a Research Fellow at the Bureau of Standards, he will compare the Swedish and American methods for determination of gases in metals on Swedish and American steels.

Conference on Electroplating

On February 2 a conference was held at the Bureau with the officers and the Research Committee of the International Association of Electrotypers. Since July first of last year, this organization has maintained a research associate at the Bureau for the study of nickel electrotyping. The results obtained in this research up to the present time were placed before the committee and discussed. The committee commented favorably upon the progress made in the work.

Satisfactory progress is also being made in the study of the protective value of nickel plating upon iron and steel, although no very promising means have yet been discovered of effecting any marked improvements.

Cast Iron for Enameling Purposes

Enamels for bath tubs, stove parts, and other cast iron wares often blister during the firing process, causing loss to the manufacturer and increased cost of the perfect product to the consumer.

The Bureau of Standards, in cooperation with the American Ceramic Society, has undertaken a thorough study of cast iron for enameling purposes with a view to determining the iron most suitable for this work, and, if possible, the cause of blistering of the enamel when fused onto castings made from certain types of pig iron. Two types of pig iron are being used in the cupola charge. It is a popular opinion among enamelers that castings made from 100 per cent pig iron of these two types cause blistering of the enamel, while this condition is remedied somewhat by adding scrap castings to the melt.

Communicated by the Director of the Bureau of Standards, Dr. G. K. Burgess.

In each of the first two experimental runs of castings, 100 per cent of the above mentioned pig iron was employed.

Sample castings were enameled both in the laboratory and in the plants of various manufacturers. The enamels used are designated by the trade as the wet and dry process enamels. The wet process enamel is ground fine and suspended in water as a slip, using clay as the floating agent. This slip is sprayed onto the casting, dried and fused at comparatively high temperatures. The dry process enamel is also fused at these temperatures, but the casting is first heated and the dry enamel powder sifted on to give a smooth coat.

The results of the enameling of the first runs of castings have been checked. It was found that blistering occurred in the enamel on all castings except those on which the single coat wet process enamel was fused at comparatively low temperatures. The blisters appeared as pinholes in the enamel and as dimples on the surface where the enamel was too thick or viscous to allow the bubbles to "blow" through. The highest temperature at which no blistering occurred was 1290 degrees Fahr. Above this temperature unsatisfactory results were obtained. No conclusions have been drawn, since the investigation is not far enough advanced. Further work has been planned to include varying cupola charges from which castings are to be enameled, both in the laboratory and in commercial plants. Chemical, metallographic, and spectroscopic analyses will be made of the castings before and after enameling, in order to determine any changes which might take place, due to the enameling process. This report covers the results obtained with 75 castings. It is estimated that a similar number will be used from each cupola run.

Standard Sample No. 12c

Renewal No. 12c of standard sample of Basic Open Hearth 0.4 per cent Carbon Steel is ready for distribution with a provisional certificate, and will be sent out as soon as the name labels are received from the Government Printing Office.

Design of Specimens for Short-Time "Fatigue" Tests

Technologic Paper No. 275 of the Bureau of Standards deals with the design of specimens for short-time fatigue tests. This publication may be obtained from the Superintendent of Documents at 5 cents per copy.

Although the so-called "short-time fatigue test" does not appear likely to replace the endurance-run test, the Bureau has found sufficient correlation between the two to make further study worth while. In these two types of test the controlling factors in the design of specimens are different. In endurance runs it is necessary to secure failure at a place where the stresses are determinate and calculable. The highest stress occurs in a free portion of the specimen far enough from the clamps of the testing machine to be calculated by the elementary Euler-Bernoulli theory. Therefore, the shape of the specimen must be chosen so as to provide for a maximum of stress sufficiently removed from clamps and fillets to be calculated by this simple theory, and large enough to exceed any local stresses near the clamps.

On the other hand, in the short-time "fatigue" tests, failure is not desired. Therefore, there is no necessity for providing a maximum of stress on a free portion of the specimen. In addition, the intermediate stresses concentrated in the neighborhood of the clamps contribute only a small part to the deflection or temperature rise, so that there is no practical disadvantage in allowing them to be higher than those in the uniformity stressed free portion of the specimen. Those limitations which determine the design of endurance-run specimens, therefore, do not apply to short-time tests. It is possible, then, to design a specimen for short-time test with maximum stresses uniform over a large portion of the material, thus securing greater sensibility. This should be the controlling factor in the design of these specimens.

Specimen shapes are shown, which are suitable for different types of short-time "fatigue" tests. Because of the simple shape of the specimen, the Sondericker type of machine is deemed the best suited for these tests.

The Corrosive Action of Various Soils

Panoramic pictures have been made of the specimens of pipes removed from the ground in 1924 in the course of the Bureau of Standards soil corrosion investigation. These pictures, which are six inches wide and as long as the circumference of the pipe, show quite clearly the size and distribution of the pits, and where supplemented by the available data on the individual corrosion losses, are very helpful in the study of the effects of the soil on pipe materials. Individual pictures or complete sets of prints may be purchased by those desiring them.

Plastic Refractories

Clay refractories, furnished to the trade in their plastic form, are rapidly supplanting special shapes in boiler settings and similar installations. The demand for this material for repair work is also rapidly increasing, so that at the present time it has been estimated that the total daily output exceeds 100 tons. Because of the increasing importance of this commodity to the trade, and the fact that the Government is contemplating the formation of specifications for its purchase, the Bureau of Standards undertook to determine the physical and chemical characteristics of several commercial brands of these plastic refractories.

Test specimens, made by hand-ramming in molds, were burned, subjected to standard and modified tests for fire clay refractories, and also analyzed chemically and petrographically. The information obtained indicates that plastic refractories as now furnished to the trade are inherently the equivalent of the highest grade fire clay brick.

A comparison of softening point determinations and chemical analyses by three independent laboratories shows that a variation of from one-half to one cone in softening point determinations, and more than 5 per cent on some constituents in chemical analysis, can be expected for different samples representing one brand of product.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment — Members Submitting Answers and Discussions Are Requested To Refer to Serial Numbers of Questions

NEW QUESTIONS

QUESTION NO. 148. *What is the relative proportion of basic open hearth and acid open hearth steel being produced at present, and is there a trend toward increased relative production of either?*

QUESTION NO. 149. *Do plates of basic open hearth steel ever have a higher base rate than acid open hearth steel?*

QUESTION NO. 150. *Is it possible to determine by means of test or examination whether a given piece of steel has been made by bessemer, open hearth, or electric furnace process?*

ANSWERS TO QUESTIONS

QUESTION NO. 137. *What is the mechanism of the iodine etch for the deep etching of steel?*

QUESTION NO. 138. *Is the electrolytic pickling process being used to show up defects in steel bars? If so, how does it compare with the regular pickling processes?*

QUESTION NO. 142. *What is the consensus of opinion of the cause of blisters in low and high grade steel sheets?*

QUESTION NO. 143. *How can these blisters be eliminated?*

QUESTION NO. 144. *Why do many chromium-nickel steels show a laminated structure when viewed under the microscope?*

QUESTION NO. 145. *How will the cutting qualities of a lathe tool made from an 18 per cent tungsten steel be affected by quenching from 2400 degrees Fahr. and tempered at 1100 degrees Fahr. as compared with a similar tool quenched from 2300 degrees Fahr. and tempered at 1100 degrees Fahr.?*

ANSWER. The answer to this question is an excerpt from the paper by H. J. French, Jerome Strauss and T. G. Digges, entitled "Effect of Heat Treatment on Lathe Tool Performance and Some Other Properties of High-Speed Steel," published in TRANSACTIONS, September, 1923, page 353.

The endurance of high-speed steels is affected to a marked degree by the high-heat temperature used in hardening and rises rapidly with increase above 2200 degrees Fahr. However, a point is finally reached where a further temperature rise is no longer attended by a commensurate increase in the endurance and if high enough heats are employed, a decrease will be observed coincident with a partial melting of the steel. Under otherwise fixed conditions there is therefore a high-heat temperature which results in maximum endurance, but this varies with composition. It is higher in the 18 per cent tungsten than in the 13 per cent tungsten steels and is raised in both types by the addition of 3 to 5 per cent cobalt.

The best hardening temperatures for the four main types of high-speed steel, to be used as lathe tools under severe service, are considered to be about as follows:

2350 degrees Fahr. for low tungsten-high vanadium steel.

2400 degrees Fahr. for high tungsten-low vanadium and low tungsten-cobalt steels.

2450 degrees Fahr, for high tungsten-cobalt steel.

These temperatures are a compromise between several factors including tool endurance and brittleness.

The endurance of high-speed steels is likewise dependent upon and within limits, increases with the time at high heat. In tests made with high tungsten-low-vanadium steel, tools held 3 minutes at 2280 degrees Fahr. had superior endurance to those held 50 seconds at 2400 degrees Fahr., but were not as good as those subjected to the latter temperature for 1½ minutes. Therefore, for consistent results both time and temperaure should be controlled by suitable instruments.

High-speed steels subjected to the severe service described were found to have endurance characteristic of the high temprature treatment used in hardening, and this was not modified to any great degree by any subsequent tempering up to and including 1100 degrees Fahr. However, the higher the tempering temperatures the tougher did the steel become. Thus the most important reason for tempering, in this case, is not increased endurance but decrease in brittleness.

QUESTION NO. 146. ***What causes a carburized automotive ring-gear to enlarge or close up in the hole?***

The steel used was S. A. E. 1020; normalized one hour at 1700 degrees Fahr.; cooled on the floor; machined. Carburized 7 hours at 1600 degrees Fahr.; cooled in pot.

Heat treatment given was:

1650 degrees Fahr. for core; quenched in oil.

1440 degrees Fahr. for case; quenched in water—drawn in oil 10 minutes at 400 degrees Fahr.

QUESTION NO. 147. ***Is it desirable or necessary to periodically anneal the chains used on cranes? If so, why?***

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

CARBURIZATION OF IRON AND STEEL. By Harry S. Cooper, metallurgist, James H. Knapp, Industrial Furnace Engineer, in *Western Machinery World*, March, 1925.

The author has reviewed the methods employed in the carburization process, which application dates back to the sixteenth century, from early times to the present time. Now, the application of the process is limited almost entirely to the production of superficially carburized parts for case hardening. The method of carrying out the work has not changed very much in principle, and the author points outs that we now know the precise rules to be followed in order to secure given desired results, and have available accurate means of carrying out these rules.

COMBUSTION DEVICES FOR SOLID FUELS. By Prof. W. Trinks, Carnegie Institute of Technology, in *Fuels and Furnaces*, March, 1925, page 233.

This article discusses in detail a number of devices for the burning of solid fuels, and gives illustrations showing the same. Particular attention is given to the burning of bituminous coal, inasmuch as it is employed more than other solid fuels.

TRACE HEAT LOST THROUGH WALLS. By M. L. Hartmann, director of research and O. B. Westmont, research chemist, Carborundum Co., Niagara Falls, N. Y., in *Foundry*, March 15, 1925.

The above paper was prepared for the American Electrochemical Society and the authors have found the following statements to be true: That refractory materials should resist heat is a basic requirement in furnace operation. Those which conduct the heat away from the surface quickly, usually excel. To obtain the middle ground between heat resistance and conductivity requires some accurate determination of the latter property.

OUTSTANDING DEVELOPMENTS IN FUELS ENGINEERING AND RESEARCH DURING 1924. By H. W. Brooks, fuel engineer, U. S. Bureau of Mines, in *Mechanical Engineering*, Vol. 47, No. 2, 1925, page 145.

This report, prepared at the request of the fuels division of the American Society of Mechanical Engineers, gives a review of the important developments made in fuels enginering and research during the past year. It is pointed out that, except in the field of scientific coal and gasoline technology, developments during the year in fuels engineering, have not involved the discovery of new fundamentals but rather the restatement of old principles in forms more adaptable for efficient and durable service.

MELTING WITH HIGH FREQUENCY. By Dudley Willcox, Ajax Electrothermic Corp., Trenton, N. J., in *Iron Trade Review*, February 26, 1925, page 567.

This article describes a furnace designed for high frequency currents. Commercial installations have been made for producing alloys of nickel-iron, gold-platinum, osmium-iridium and other metals which require high temperatures, freedom from contamination and thorough mixing. High frequency furnaces also are used commercially for melting metals of the tungsten group in graphite containers for producing carbides.

HEAT TREATING STEEL ELECTRICALLY. By E. F. Collins, consulting engineer, industrial heating department, General Electric Company, Schenectady, N. Y., in *Forging-Stamping-Heat Treating*, February, 1925, page 41.

This article states that the use of the electric furnace does not call for new methods of manipulation of present heating processes, but rather fits itself into standard and generally accepted heat treating requirements admirably, removing practically all uncertainties connected with the proper application of heat and eliminates almost entirely the handicaps inherent in fuel-fired furnaces.

MAGNETIC AND PHYSICAL HARDNESS. By Dr. John A. Mathews, Crucible Steel Company of America, New York, in *Iron Age*, March 5, 1925, page 689.

The above is an abstract of the second part of the annual Henry M. Howe Memorial lecture delivered by the author at the annual winter meeting of the American Institute of Mining and Metallurgical Engineers on February 16, which was entitled, "Austenite and Austenitic Steels." This was divided into two parts. The first part, which dealt with austenitic steels, was a presentation of a cross section of the field in which are found those steels of maximum general resistance to corrosion, maximum physical properties at actual high temperatures and maximum resistance to scaling at elevated temperatures. Four types of steels were discussed; first, the high nickel steels containing 25 per cent and higher; second, the high chromium steels; third, the high chromium-nickel steels in which nickel is usually higher than the chromium and to which a substantial amount of silicon has been added. The second part of the lecture gives the results of some recent research work undertaken to answer a question raised by himself some ten years ago.

METALLOGRAPHY OF NON-FERROUS METALS. By J. K. Wood, consulting engineer, New York City, in *American Machinist*, March 12, 1925, page 433.

The heat-treatment of non-ferrous metals is discussed. Constitutional diagrams of zinc-copper and copper-aluminum alloys are given. The characteristics of duralumin in the copper-aluminum group are covered and lists of the leading alloys given.

(*Continued on page 556*)

Reviews of Recent Patents

By
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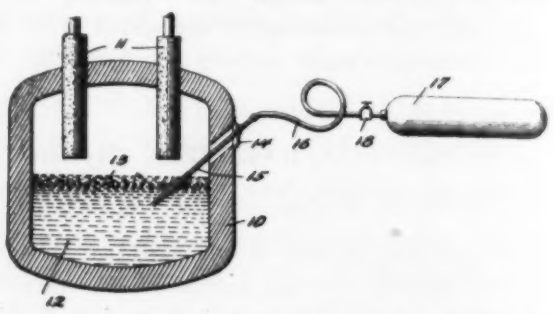
Member of A. S. S. T.

1,513,735, Method of Manufacturing Low Carbon Steels, Henry C. Bigge, **of Bethlehem, Pennsylvania.**

This patent describes a method of manufacturing low carbon alloy steels, whereby ferro alloys containing the usual commercial percentages of carbon can be used without increasing the carbon content beyond the desired limit.

In the manufacture of the alloy, the scrap or other material is melted in an electric furnace 10 and oxygen under pressure is injected into the



bath 12 below the slag surface 13 by means of a tube 15, which is connected with a suitable oxygen cylinder 17. The forcing of the oxygen into the bath has two purposes: First, it burns out the carbon, reducing the carbon content to the desired limit, and, second, it raises the temperature and fluidity of the bath, so that a more satisfactory combination of the alloying ingredients with the molten iron or steel is obtained. In use, the ends of the tubes 15 are melted off quite rapidly, so that it is desirable to use long tubes.

1,514,064, Alloy Intended for Castings, Ambrose Joseph Mandell, of Forest Hills, New York.

This patent describes an alloy intended for castings, and resistant to oxidation at a high temperature. Most high temperature-resisting alloys heretofore have contained chromium as the essential and indispensable ingredient. As chromium is usually the most expensive ingredient of these alloys, this invention proposes to secure an alloy of equally desirable properties without the use of chromium.

The alloy consists essentially of nickel, or cobalt, and silicon, the silicon being in proportions of 2 to 16 per cent, the balance being nickel. The addition of iron in amounts of from 5 to 40 per cent does not materially lower the resistance to oxidation at high temperatures, and the addition of a small

percentage of aluminum (not over 3 per cent) tends to produce sounder castings, and also to increase the resistance to oxidation. Carbon may be present in amounts not exceeding 2 per cent, without harm to the heat resisting properties.

1,518,607, **Treatment of Case-Hardening Baths, Porter W. Shimer, of Easton, Pennsylvania.**

In the United States patents 1,279,457 and 1,279,458, this inventor has described a case-hardening bath containing such mixtures as calcium chloride and sodium chloride or potassium chloride and sodium chloride, which mixtures are subjected to the action of calcium cyanamide immersed therein, to impart case-hardening properties. In use, these baths deteriorate in case-hardening properties, especially where the melt is contained in cast-iron pots, or where the articles being case-hardened are coated with scale or sand, and from other causes. To restore the case-hardening properties or activities to such a bath, the present patent describes subjecting the bath to a deoxidizing metal to clean the same and then subjecting the bath to calcium cyanamide to restore the case-hardening activity. In use the metal preferred is metallic aluminum, and about 1 ounce of the aluminum per hundred pounds of salt mixture is prescribed.

1,520,033, **Alloy, Stuart Evan MacGregor, of Windsor, Ontario, Canada.**

This patent describes an alloy primarily used for cutting purposes in machining of cast iron and soft steel at high speeds, and which, when necessary, will take and maintain a razor edge.

The alloy preferably consists of 14 per cent nickel, 27 per cent cobalt, 28 per cent tungsten, 31 per cent chromium, and about 1.25 per cent carbon. In producing the melt, the nickel and cobalt are placed in the bottom of the crucible, the chromium is placed in a layer over them, the tungsten mixed with boron carbide in sufficient amounts to produce the desired carbon content is placed over the chromium, and the entire charge is covered with a layer of broken glass. Upon heating, the glass melts, and forms a protecting slag layer which prevents any loss of carbon and protects the bath from oxidation.

1,520,063, **Manufacture of Steel, Paul Richard Kuehnrich, of Sheffield, England.**

This patent describes a case-hardening mixture comprising a relatively inert salt such as barium chloride or calcium chloride, which is activated by other fusible salts containing boron, carbon and nitrogen.

The preferred composition is 95 per cent barium chloride and 5 per cent calcium borate, potassium carbonate and potassium ferro-cyanide in equal proportions by weight.

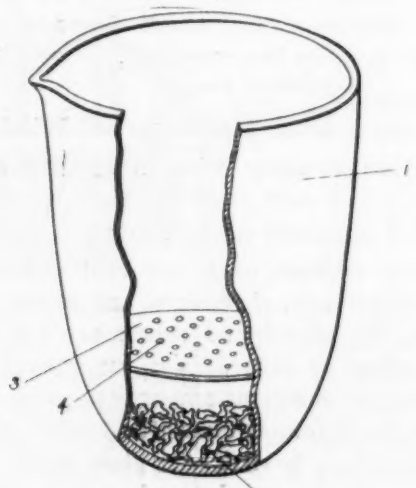
According to the inventor's theory, the boron penetrates the article being treated, and acts as a catalyser for the diffusion of carbon and nitrogen throughout the surface of the same.

1,520,744, Bath for Heat-Treating Metals, Arthur E. Bellis, of New Haven, Connecticut, assignor to the Bellis Heat Treating Company, of New York, N. Y., a corporation of Connecticut.

This patent describes an improved case-hardening bath possessing a high degree of fluidity and a wide range of working temperatures without appreciable volatilization. The preferred composition is 52 per cent potassium chloride and 48 per cent sodium carbonate, which is the eutectic mixture of these salts. The eutectic mixture has the lowest melting point of any comopund of these salts, which is substantially lower than the volatilization points of any of the ingredients, and when used at ordinary working temperatures, is highly fluid.

1,522,605, Manufacture of Steel and Low Carbon Iron, Octavio Undurraga, of Santiago, Chile.

This invention proposes a substitute for the Bessemer process of producing low carbon iron and steel, by inserting in the bottom of a crucible a compound or mixture which, when heated, is caused to liberate oxygen. In

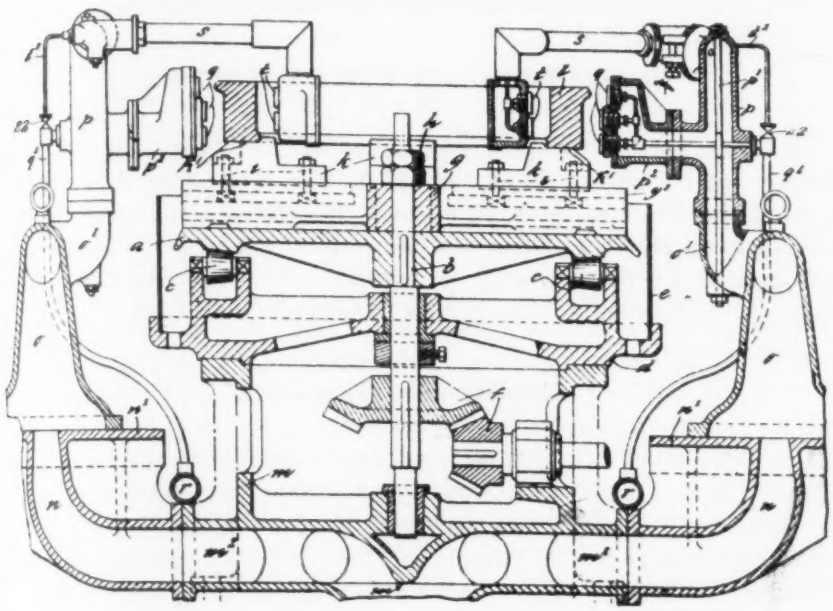


the preferred method of following the invention, a mixture 2 of calcium carbonate and nitrate of soda is placed into the bottom of the crucible 1, a perforated plate 3 is placed on this mixture to prevent scattering and floating of the mixture in the metal when poured therein, molten iron is poured into the crucible to fuse the plate 3, and to mix with the oxygen liberating materials 2, so that oxygen liberated by the compound under heat will burn out the carbon in the molten iron, and the slag materials formed will float on top of the bath and may be skimmed off.

1,524,578, Heat Treatment of Steel Tires and Wheels, Christer P. Sandberg, of London, England.

This patent relates to an improvement in quenching apparatus for wheel tires, whereby the tires may be quenched on both the inner and outer

surfaces so as to overcome the tendency of the tires to leave the body of the wheel when fracture occurs. In the practice of the invention, the tire L is mounted on the chucks k on the rotating platform a, driven by suitable gearing f, and both the inner and outer surfaces are subjected to a cooling



fluid from the nozzles q and t. To permit removal and replacing of the tire on the chucks k, the pipes s which convey the cooling fluid to the nozzles t are pivoted to swing out of the path of the tire.

1,525,027, **Sand Casting, John N. Early, of Pittsburgh, Pennsylvania, assignor to W. J. Early Sons Foundry Corporation, of Pittsburgh, Pennsylvania, a corporation of Delaware.**

This patent describes an alloy capable of taking a chill or chill surface in a sand mold without the use of chill molds or chill pieces in the mold.

The alloy is preferably composed of silicon, 0.75 to 1.50 per cent; sulphur, 0.05 to 0.25 per cent; phosphorus, 0.25 to 0.75 per cent; manganese, 0.20 to 0.70 per cent; total carbon, 2.25 to 3.75 per cent; combined carbon, 1.00 to 2.25 per cent; iron, approximately sufficient to make 100 per cent, and when cast, forms a chill in either sand or chill molds. The depth of the chill in the finished casting is controlled primarily by the pouring temperature, but also may be controlled somewhat by varying the sulphur content.

News of the Chapters

STANDING OF THE CHAPTERS

IN the March issue of TRANSACTIONS appeared the relative standing of the 29 chapters of the Society as of January 1, 1925, and as of February 1, 1925. The tabulation which appears below shows the relative membership standing of the chapters on March 1, 1925. For the convenience of ready comparison, the standing as of February 1, 1925, is included. It will be noted that there are three changes in Group I, two changes in Group II and three in Group III.

Standing as of February 1

I	II	III
1. CHICAGO (275)	1. Hartford (128)	1. Tri City (59)
2. Detroit (274)	2. Lehigh Valley (117)	2. LOS ANGELES (55)
3. Cleveland (272)	3. Golden Gate (104)	3. Rochester (54)
4. Pittsburgh (265)	4. Milwaukee (79)	4. New Haven (52)
5. Philadelphia (250)	5. Syracuse (73)	5. Washington (49)
6. Boston (216)	6. Cincinnati	6. Rockford
7. New York (203)	7. Indianapolis	7. Worcester
	8. Buffalo	8. Schenectady
	9. ST. LOUIS	9. PROVIDENCE
	10. North West	10. South Bend
		11. Springfield
		12. Toronto

Standing as of March 1

I	II	III
1. CLEVELAND (283)	1. Hartford (128)	1. Tri City (61)
2. Detroit (278)	2. Lehigh Valley (116)	2. Los Angeles (56)
3. Pittsburgh (272)	3. Golden Gate (103)	3. Rochester (55)
4. Chicago (270)	4. Milwaukee (75)	4. New Haven (52)
5. Philadelphia (253)	5. CINCINNATI (72)	5. Washington (50)
6. Boston (223)	6. Syracuse	6. Worcester
7. New York (207)	7. Indianapolis	7. Schenectady
	8. Buffalo	8. Rockford
	9. St. Louis	9. Providence
	10. North West	10. South Bend
		11. Springfield
		12. Toronto

BUFFALO CHAPTER

THE Buffalo chapter of the American Society for Steel Treating held a meeting on February 24 at 8:15 p. m., in the Hotel Buffalo. The minutes of the January 26 meeting were read and approved. G. A. Richardson of the Bethlehem Steel Company gave an illustrated lecture on the manufacture of steel which covered the two kinds of ore mines, surface and underground; the blast furnace and operations for making the iron; the Bessemer process for making steel; the rolling mills for sheets and rods; pressing and rolling car wheels and the manufacturing of fence and barb wire. The meeting adjourned at 10:15, there being about 80 members and guests present.

CHICAGO CHAPTER

The Chicago chapter of the A. S. S. T. held its regular March meeting on the 12th of the month. The subject for discussion at this meeting was the heat treatment of cast iron as described in a paper, compiled by Fred Grotts, M. L. Frey and E. C. Alexander, metallurgists with the Holt Mfg. Co., Peoria, Ill., and read by Mr. Frey. Summarizing the paper it stated that: Hard spots due to combined carbon can be removed by heating to 1750 degrees Fahr.; that there is a certain application for hardening and drawing cast iron; that cast iron to which steel has been added has increased tensile strength; that alloy cast iron is a field to be developed; that chilled iron can be softened, then hardened; and white iron can be graphitized quickly by heating to 1750 degrees Fahr., then being quenched and drawn.

Referring to chilled iron the paper said: That to prevent excessive scrapping of raw material and trouble from burnt tools, castings are routed directly to the heat treating department, where they are annealed (heated to 1750 degrees Fahr. for a short time), then the machining operations are given, and the parts rerouted to the heat treating department for quenching and drawing. This gives a hardness practically equivalent to the original chill and without tool trouble or loss of material. Physical tests of this treated material show a 5 per cent increase in strength over standard chilled iron.

When cylinders and pistons of soft gray iron are taken directly from the foundry to the machine shop trouble sometimes is experienced from distortion due to the relieving of strains that exist in green castings, the paper stated. When it is not possible to season these castings it is the procedure of the Holt company to anneal these castings at a temperature of about 600 degrees Fahr.

It was stated that white iron can be broken down quickly by heating to 1800 degrees Fahr. Then by quenching in water and drawing at approximately 1300 degrees Fahr. a product is obtained that is readily machineable and has good strength. High ductility, however, which is one of the essential requirements of high quality malleable iron, is lacking.

The paper cited a typical soft iron whose analysis was 3.5 carbon, 0.35 manganese, 0.11 sulphur, 0.45 phosphorus and 2.75 to 3 per cent silicon. The general properties of this cast iron were low. Its tensile strength averaged 18,000 to 20,000 pounds per square inch and its scleroscope hardness was 26

to 30. By quenching this stock from a temperature of 1550 degrees Fahr. a noticeable increase in hardness was observed. An average of 50 has been obtained in treating a large number of cylinder heads. It should be observed that when a scleroscopic hardness of 50 to 60 is obtained it is customary to draw it back to 35 to 40.

To salvage castings where defects are found on finished surfaces an alloy of copper and nickel is used in connection with the electric arc, according to the paper.

The April meeting of the chapter will be held on the 9th and will be addressed by T. H. Nelson, of the United Alloy Steel Company of Canton, on the subject of "Stainless Steel."

At the May 7th meeting, Dr. H. B. Lemon will talk on "Constitution of Solids."

CINCINNATI CHAPTER

A joint meeting of the Cincinnati chapter of the Society with the Engineers' Club of Cincinnati was held on Thursday, March 19, at 8:00 p. m., in the Literary Club Rooms. H. F. Smith presented a paper on "Industrial Heating." Mr. Smith is connected with the Smith Gas Engine Company of Dayton, as secretary and consulting engineer. He is also secretary and chief engineer of the Gas Research Company of Dayton. These companies were organized by him and for a number of years he has been engaged in fuel research. Mr. Smith stated that the application of heat to industrial purposes involves three distinct processes, first—the selection of a suitable source of heat; second—the liberation of heat from this source at the point where it is desired to develop a temperature, or the problems relating to combustion; and third—the transfer of this heat in suitable manner to the work to be heated, or problems of furnace design. The technical and commercial aspects of these problems were discussed by Mr. Smith.

The April meeting of the chapter will be addressed by J. B. Johnson, chief of the materials section, engineering division, Army Air Service, War Department, who will show the development of the use of heat treated materials in aircraft structures and in the aircraft power plant.

CLEVELAND CHAPTER

The regular March meeting of the Cleveland Chapter was held in the ball room of Hotel Winton on Monday evening, March 16, 1925, at 8:00 p. m. On this occasion, Dr. Carl Benedicks, director of the Metallographic Institute, Stockholm, Sweden, was the guest of honor and the speaker.

Dr. Benedicks chose as his subject for this lecture, "Meteoric Iron and Invar." He described an investigation which he had made a number of years ago, at a time when his attention had been called to meteorites and other nickel-iron alloys. The very careful and thorough studies which he made in the metallography of these alloys he discussed in detail. His lecture was

illustrated by a number of lantern slides, most of which were prepared from photomicrographs.

In speaking of the properties of invar, Dr. Benedicks told of his attempts to explain the remarkable physical properties of this alloy, and how he had finally decided to measure the dimensional changes which he was convinced must occur when the invar is heated. He described the apparatus devised to measure any changes occurring during the time of heating. By using this, he was able to demonstrate that such changes actually take place. He also explained why the invar shows only exceedingly slight variations in its dimensions if measured an hour or two after heat treatment. This part of the lecture included a discussion of the relation of changes in microstructure to the changes in physical properties, and was an excellent illustration of the value of microscopic examination and metallographic theory as aids in the explanation of the properties of alloys.

This was a joint meeting with the Cleveland Section of the A. I. M. M. E. About 200 members of the two societies and guests were present at this meeting and about 45 at the dinner preceding it.

Dr. Benedicks presented his first Cleveland lecture at Case School of Applied Science at 4:00 p. m. of this day. The subject discussed at this meeting was the theory of hardening steel. Through the courtesy of H. M. Boylston, professor of metallurgy, Case School of Applied Science, who had extended an invitation to all those interested in this work to attend this meeting, a large assemblage of Cleveland engineers and scientists were present.

A. S. Towsend.

DETROIT CHAPTER

The Detroit chapter of the Society held a Hardness Testing Symposium at their meeting on February 16th. The speakers were H. A. Weaver of the Steel City Testing Laboratory; C. E. Hellenberg of the Wilson-Maeulen Company and Prof. Boston of the University of Michigan. Mr. Weaver speaking first, covered the various precautions to be taken into consideration in the operation of the Brinell Machine. Mr. Hellenberg described the Rockwell instrument for measuring difference in penetration. He told the interesting history of its early development by Stanley Rockwell of Hartford and its various manufacturing evolutions until it was finally perfected in its present form. Mr. Hellenberg described some interesting applications of the Rockwell and some of the difficulties that users have come in contact with.

He mentioned the experience of a company in connection with a knife edge which was about ⅜ inches in diameter and 2 inches long. It had a very good case, file hard, but when tested with the Rockwell, it showed but about 30 hard. Upon breaking the case it showed a very good case. It was evident that the Rockwell could not punch a hole through a case of that size. After studying the problem it was found that the hardener to quench threw the pieces in a basket which permitted them to overlap each other. Taking one of the pieces that was file hard but that had a low reading, it was

rehardened, whereupon the Rockwell reading jumped up about 20 points. The same piece was hardened again and quenched in water and after this it tested as it should have in the first place, from which it was deducted that the Rockwell was testing only about half the case, inasmuch as only about half the case had been hardened. The Rockwell was penetrating through the partly hardened case and underneath to the soft part of the case and giving the whole knife a low reading. It has been found that the Rockwell will break through a case just like an eggshell, if it is less than .015 inches.

The speaker presented some interesting Rockwell readings plotted against the thickness of the case and to illustrate this, he told about taking some safety razor blades and testing them on top of a soft test block. The first razor blade tested 42; two laid one on top of the other, tested 59; three—60 and four 60.5. The speaker said the overlapping of the razor blades had the same effect as thickening the case. It was file hard and until sufficient thickness was obtained so as not to break through, a true reading could not be made. The Rockwell will break through a thin case and it was not a reading of the true hardness because that was obtained by piling the blades one on the other. The speaker brought out that if a case lower than .015 inches is obtained, the Rockwell reading drops off very suddenly. It was pointed out that due to the fact that the Rockwell is an indentation tester, it is perfectly possible to measure the diameter and figure the hardness in a similar manner as the Brinell machine. The speaker took a Brinell microscope and read the diameter of the diamond cone indentations over the scale of Rockwell C-60 down to C-0 and showed a curve giving this comparison. A person using the Rockwell becomes accustomed to checking hardness by looking at the impressions, five points being very evident to the naked eye. Mr. Hellenberg brought out the application of this machine in the testing of copper wire for hardness and showed charts giving the results.

During the discussion one speaker spoke of an error which is very common in the use of the Brinell machine in the testing of aluminum pistons. This error sometime amounts to 25 per cent, due to the operator pumping quite vigorously, resulting in impulses of the liquid, causing it to go above the U-tube and coming back with a certain impact on the oil column and causing a soft reading on the pistons.

Another common fault in the use of the Brinell machine is an improperly prepared surface which results in inaccurate reading of the diameter. It is sometimes common practice to take the part to be Brinelled and put it on a small diameter grindstone, which results in a concave surface, upon which the test is to be made. The result is an oblong shape and if it is only read one way the reading may be greater or less. It was suggested that it should be read across the two diameters and the hardness averaged.

Another common error in Brinell hardness reading is in adjusting the microscope. It is often the tendency to permit a new man on the job to adjust the microscope for readings. The adjustment of the microscope must be done very carefully if accurate results are to be obtained. In setting wires to correspond to the same distance on the engraved scale it is quite easy to

get the distance to correspond, but frequently it will throw the engraving on the lines out of focus.

Professor Boston of the University of Michigan presented a very interesting description of some features of two hardness testing machines which he examined in England last summer. The first one was the Alfred Herbert type Brinell machine which embodies most of the Brinell principles with the same load and the same point, although it can be used interchangeably with any size, even the diamond point. The load is applied mechanically and uniformly, so that the operator is responsible only for the placing of the piece, the starting of the machine and the removal of the piece. In other words, the human element is taken out of the question of hardness determination, other than the reading of the impression. Professor Boston also described the machine that is being developed at Vicars. This machine is intended also to eliminate the variable human elements. One new feature is a prism made of diamond instead of the usual steel ball. Prof. Boston brought out that for ideal Brinell reading the diameter of the impression should be ⅜ the diameter of the ball. With the type of machine described, instead of measuring the diameter and then computing the hardness the microscope is so constructed that a reading on the scale at the side gives the Brinell hardness readings direct. The Brinell readings in this machine are supposed to need no correction factors whatever.

It was brought out in the discussion that the best kind of steel for Brinell balls is made with the following composition: 1.20 to 1.40 carbon with 4 per cent tungsten and .60 chromium. It was stated that the actual hardness of these balls is only slightly greater than one having one per cent chromium and one per cent carbon. They seem to be a great deal tougher under service. During the war when it was required to run many determinations on materials 500 to 550 hard or better, results indicated that the regular chromium ball would make satisfactorily 40 or 50 determinations, while the tungsten ball would stand up with satisfaction for at least 200.

At the close of the meeting, Mr. Weaver, Mr. Hellenberg and Prof. Boston were given a rising vote of thanks for their contributions.

On March 10, 1915, the Detroit chapter of the American Society for Steel Treating held a meeting in the General Motors Building at 8:00 p. m. The subject of "High Speed Steels" was discussed by Dr. Carl Benedicks, the eminent Swedish metallurgist. Dr. Benedicks is professor of engineering of the University of Stockholm and director of the Metallographic Institute of Stockholm. Dinner was served at 6:30 p. m.

GOLDEN GATE CHAPTER

The Golden Gate chapter of the Society held a meeting on Wednesday, March 11, at the New Peerless Cafe in Oakland. The first speaker of the evening was W. R. Chambers, superintendent of the Pacific Gear and Tool Works of San Francisco, who talked on the "Reminiscences of a Gear Manufacturer." Mr. Chambers, being one of the pioneers in the gear industry

in California, has been in it continually during the most of an active life and his presentation was most interesting and was very well received. The second half of the evening was devoted to the fourth of the series of lectures on steel, which was entitled, "Alloy Steels and Their Uses," presented by E. H. Kottnauer. The speaker's years of experience in this work, particularly as traveling metallurgist, have made him familiar with a great many of the problems of the alloy steel manufacturer and user, and a lengthy discussion followed his presentation. The evening closed with a vote of thanks to the speakers for their successful efforts. There were over 60 members and guests in attendance at the meeting which was a most enthusiastic one.

D. H. Grubb.

HARTFORD CHAPTER

The March meeting of the Hartford chapter of the Society was held on the 10th of the month at the Hartford Engineers' Club, at 7:45 p. m. W. S. Bidle, president of the A. S. S. T., and W. H. Eisenman, secretary, were in attendance at this meeting. Mr. Bidle, who has had 30 years of experience in heat treating, spoke on "Heat Treating Equipment." Mr. Eisenman discussed the past, present and future activities of the Society. An informal dinner was held at the University Club at 6:30 p. m., preceding the meeting.

INDIANAPOLIS CHAPTER

An illustrated lecture on "Indiana Limestone" was the feature of the March 9th meeting of the Indianapolis chapter of the A. S. S. T., which was held in the Y. M. C. A. auditorium. This lecture, which was given by H. S. Brightly, technical director, Indiana Limestone Quarrymen's Association, Bedford, Indiana, has been presented before the largest organizations in the United States, and is a part of the courses taught in several of the largest universities of the east and midwest. Mr. Brightly's presentation was very interesting. He gave many astonishing figures concerning Indiana limestone, its uses, strength, ability, origin, etc. He claims it is the best stone for general use on the market and stands fire next to brick. It has very little difference in strength, due to direction and will undergo about 7000 pounds to the square inch. Mr. Brightly showed three films on the quarries of southern Indiana and also 60 slides showing where Indiana limestone has been used and how well it stands up under any and all types of architecture. Dinner was served at 6:30 p. m. preceding the meeting. *H. A. Maves.*

LEHIGH VALLEY CHAPTER

A joint meeting of the Lehigh Valley chapter of the A. S. S. T. and the Engineers' Club of the Lehigh Valley, was held on Friday, April 3, at 7:30 p. m., in the Exhibition Building of the Bethlehem Steel Company. The speakers discussed "Electric Welding of Steel and Cast Iron, Gas Weld-

ing and Cutting, and Thermit Welding.'' Motion pictures were also shown, giving demonstrations of liquid oxygen, electric, gas and thermit welding.

LOS ANGELES CHAPTER

On Wednesday evening, February 4, the Los Angeles chapter of the American Society for Steel Treating assembled at the California Institute of Technology, Pasadena, and spent the entire evening as guests of the faculty and student body of the mechanical engineering branch of the university.

Professor Clapp of the university faculty, who has been a very active member of the Los Angeles chapter of the A. S. S. T., presented the chapter membership to the student branch of the American Society of Mechanical Engineers at the university, and under the guidance of these student members a trip was taken through the various laboratories and shops in connection with the Norman Bridge Laboratory of Physics.

Following the tour of inspection the members were assembled in the lecture room of the Norman Bridge Laboratory of Physics, and Dr. E. O. Watson gave a very interesting demonstration talk on the facilities of this large auditorium for conducting experimental and research work in the presence of a large assemblage.

Dr. Whitney, another member of the university staff, by the projection of light through specimens and upon a projection screen, gave a very interesting demonstration of the formation of crystals.

The meeting was then turned over to Dr. William N. Lacey, in charge of the Department of Chemical Engineering at the university, and Dr. Lacey brought the members back to iron and steel from the fanciful regions of physical phenomena. Dr. Lacey's subject was the Chemical Analysis of Steel, and since the determination of the carbon content and the manganese content are the most common and important determinations in steel plant practice, he had the apparatus set up for and explained in detail the most common methods of procedure. To one schooled in chemical analysis, the determination of the amount of carbon in a given sample of steel is very simple, but to one who has not had the laboratory training and perhaps has never even been inside a chemical laboratory the procedure is more or less of a mystery; yet Dr. Lacey's explanation was so clear that every one who heard him felt they could, with little or no practice, carry out the analysis very accurately.

To determine the percentage of carbon present in steel the operation in a general way is to burn the carbon out of a weighed sample of the steel, collect the carbon dioxide formed, determine by weighing or measuring by volume the amount of carbon dioxide, and from that amount of carbon dioxide which has been produced the amount of carbon can be determined and the percentage of the weighed sample of steel used, found. To accomplish this, apparatus consisting of two U-tubes, one for collecting by filtration through an absorbent the carbon dioxide which may filter into the apparatus

from any source, the second U-tube for collecting any moisture, by filtration through an absorbent, usually a caustic; then comes a silica tube of perhaps eighteen to twenty inches in length, the central part of the tube passing through an electric furnace; connected to the silica tube is another U-tube for another moisture filtration; and then comes the absorption bulb which contains a known amount of some reagent which will combine with carbon dioxide.

The method of procedure is as follows. A weighed sample of the steel is put in a heat resisting container, and the container placed into the part of the silica tube passing through the electric furnace (usually the container is slipped into a nickel tube which acts as a liner for the silica tube, preventing any particles from splashing upon the silica and thus injuring it). An oxygen bottle or any source of pure oxygen is connected up with the first of the two filtering U-tubes, and oxygen is allowed to pass through the apparatus and over the steel as it is heated. The carbon of the steel unites with the oxygen, and the carbon dioxide thus produced is collected in the absorption bulb. When the operation is completed the container which originally held the weighed sample of steel now holds only pure oxide of iron and the other alloy metals, and the carbon has all been formed into carbon dioxide which in turn is absorbed in the absorption bulb.

To determine the amount of carbon which united with oxygen in a given operation two methods are used, one called the volumetric method and the other the gravimetric method. In the volumetric a known amount of a known reagent is used to absorb the carbon dioxide, and by adding a known amount of reacting solution until the entire is neither acid nor alkaline in character, the amount of carbon may be easily calculated. The other method, the gravimetric method, depends upon the relation of the weight of the absorption bulb before the carbon dioxide has been generated and the weight after it has been absorbed. From this difference in weight, which is the weight of the carbon dioxide itself, the carbon may be calculated.

As may be seen, this apparatus while simple in action is rather complicated in its construction, with many connections and chances for leaks; so it is the customary practice to run samples of known carbon content at frequent intervals as a check on the accuracy of the apparatus. In this way the analysist is kept familiar with his apparatus, and this familiarity makes it possible to get carbon determinations in open hearth steel plants in from six to seven minutes from the time the sample is taken from the furnace. This speed is all the more remarkable when it is taken into consideration that the sample must be cooled and either drilled or pulverized to get the fine particles necessary for testing.

The manganese determination is a somewhat different procedure. In this determination the sample of known weight is dissolved in dilute nitric acid and then silver nitrate is added to make the solution up to a known volume. One-tenth of this volume is then taken as a sample. Ammonium persulphate is added to the sample and it is then submitted to the heat of nearly boiling water, this heat completing the oxidation, and potassium permanganate is formed with the manganese present in the sample of steel.

Potassium permanganate has a distinctive color, the color growing darker as more of the permanganate is present, and it is upon this presence of color that the determination depends. In running this determination a sample of known manganese content is run along with the sample of unknown content and subjected to the same treatment and conditions; then after the potassium permanganate has been formed in both, the relation of color of the unknown with the known determines the amount of manganese present in the unknown. To determine this color relation with the eye alone is rather uncertain so a colorimeter is employed, the colorimeter being an apparatus which permits light to travel through two columns of liquid from the bottom upward. The sides of the liquid containers are opaque. This light then passes through two tubes which may be raised or lowered into the columns of liquid; the shafts of light are then either observed with the eye or thrown upon a screen where they appear as two blotches of color side by side. In operation the known sample is a column of known height, the plunger is raised or lowered in the unknown sample so that the two colors when projected are identical, and the determination is based upon the fact that the longer the column of liquid is through which the beam of light passes, the more intense the color, and vice-versa. Relations have been worked out so that these comparisons of column lengths may be read on a scale.

Dr. Lacey asked for questions during his talk and after he had finished, but there were no questions to be asked; his explanations and descriptions had been most complete. Professor Clapp then announced that each Friday evening there was a demonstrated research lecture in the Norman Bridge Laboratory auditorium, and he extended an invitation to all of the members to be present at any or all of these meetings.

After a rising vote of thanks to Dr. Clapp, his faculty associates, and the student members of the American Society of Mechanical Engineers for the very enjoyable and instructive evening the meeting adjourned.

The Los Angeles chapter of the American Society for Steel Treating held a meeting on March 4 in the Administration Building of the Central Manufacturing District. Dinner was served in the club dining room, and was followed by an interesting and profitable talk by James Knapp, furnace engineer. Mr. Knapp furnished blackboard illustrations covering practically every design and type of furnace, showing likewise the method of fuel application. Following the discussion, the meeting adjourned to Mr. Knapp's warehouse, where three or four furnaces were in operation. The meeting proved to be very satisfactory, and continuing the schedule of educational meetings, the next meeting will be held at the California Institute of Technology, the subject being, "Physical Testing." *W. H. Laury.*

NEW HAVEN CHAPTER

The New Haven chapter of the Society held a meeting on Friday, March 27, in the Winchester Club House, which was addressed by J. H. G. Williams, general manager of Kilborn and Bishop Co., New Haven, on the subject of

"Drop Forgings." An interesting and instructive discussion followed the presentation of this paper.

NEW YORK CHAPTER

Second Annual Follies

Once a year the New York chapter gives its members the chance to forget all of life's hardness and fatigue and enjoy the Follies. The second annual smoker was held in the Banquet Room of the Fraternities Building on Tuesday, March 18, 1925. Chairman E. E. Thum delivered the address of welcome (limited to 45 seconds) and it is here vouched that he did not exceed the time limit. The chapter had as its guests four of the national officers, President W. S. Bidle, Vice-President R. M. Bird, Secretary W. H. Eisenman and Director P. D. Merica. In addition to the national officers, the chapter entertained as special guests: F. F. Lucas, Henry Marion Howe Medalist, 1924, and Sam Tour, past chairman of the New York chapter, J. J. Crowe, former chairman of the Philadelphia chapter and at present affiliated with the New York chapter, and A. O. Fulton of Boston, member of the National Finance Committee A. S. S. T. and general chairman of the Boston Convention Committees. The other past chairmen, G. L. Norris, Frank P. Fahy and W. F. Graham, were unable to be present.

All of the Jerseyites and Long Islanders missed the last train home but did not express any regret, since they had the opportunity to enjoy the side-splitting, entrancing, stupendous and exhilarating entertainment, under the direction of Edwin P. Gaffney, chairman of the Entertainment Committee. After a six-course dinner and during the digestive period, a cross-word puzzle was worked (by some), prizes being won by Dr. St. John, et al.

J. O. Rinck had charge of the satisfying banquet and discharged his duties with a great degree of thoroughness. In remembrance of the occasion, souvenirs were distributed under the chairmanship of L. R. Seidell. These were furnished by the General Alloys Company, Doehler Die Casting Company, Vanadium Alloys Steel Company and International Nickel Company.

Alexander Gobus, by his contribution to the occasion in the production of rhythms, songs and parodies, retained his title as "Poet-Laureate" of the A. S. S. T. Samples of his work are as follows:

Parody, "It Ain't Gonna Rain No Mo'"

Words by "Mike" Roscape — Music by "Duck" Tility

Verse

Went over to the meeting
Of steel to get a peep.
The smoke it was so heavy
That I fell fast asleep.

Chorus

Oh! The New York Chapter is the BEST,
Of that there is no doubt.
If you do not think that it is so
Stand up, and we'll throw you out.

The song was concluded by stating that the "Brinell of finished Chorus" must be not less than 946.

□

SONG DEDICATED TO THE PEDDLERS OF THE NEW YORK CHAPTER

"Cows may come and Cows may go,
But the Bull goes on forever."

□

Words by Pearl Lite Music by Bill Ette

Tune: "Yes, We have no Bananas"

Yes, we have no test for hardness,
We have no test for hardness today,
We have Herbert and Turner and Rockwell and Brinell,
And all kinds of theory, and say
We have that old-fashioned file test,
The blacksmith says that it's best,
But yes, we have no test for hardness,
We have no test for hardness today.

The high-class vaudeville entertainment met with the entire approval of the Broadway censors. All of the members of the Entertainment Committee, including the genial secretary, T. N. Holden, C. H. McKnight, C. H. Von Schlutter, Judge Cone and the others already mentioned deserve credit for the successful results of the smoker.

NORTH WEST CHAPTER

The members of the North West chapter of the Society held a meeting on March 23, at 8:00 p. m. at the Minneapolis Steel and Machinery Company. The feature of the evening was a round table discussion on "Heat Treatment and Plant Troubles."

The chapter held a joint meeting with the Minnesota section of the American Chemical Society, and the Minnesota section of the American Society of Mechanical Engineers in the ball room of the Minnesota Union at the University of Minnesota, on Monday evening, March 30, at 8:00 p. m. The speaker of the evening was Dr. Carl Benedicks, director of the Metal-

lographic Institute at Stockholm, Sweden, the subject of his paper being "The Theory of High Speed Steel." Dr. Benedicks is a man of international reputation and is recognized throughout the world as an authority in his field. He has received high honors from scientific organizations in England, France and Germany, as well as his native country.

PHILADELPHIA CHAPTER

The members of the Philadelphia chapter of the A. S. S. T. were invited to attend a meeting of the Philadelphia section of the American Society of Mechanical Engineers, held on Tuesday, March 24, in the Engineers' Club. "Heat Treatment and Why," was the title of an illustrated talk by H. C. Knerr, chief metallurgist, Naval Aireraft Factory, Philadelphia, and director of a course in Heat Treatment and Metallography of Steel, held at Temple University, and chairman of the Philadelphia chapter of the A. S. S. T. Prof. Bradley Stoughton, head of the department of metallurgy, Lehigh University, Bethlehem, Pa., also presented an illustrated paper entitled, "Heat Treated Steels: Their Application in Engineering Work." The third feature of the evening was a two-reel motion picture entitled, "The Story of the Heat Treatment of Steel," which was presented through the courtesy of the Bureau of Mines at Pittsburgh.

The Philadelphia chapter of the A. S. S. T. held a meeting on Friday evening, March 27, at 8:00 p. m., in the Engineers' Club, at which time, E. C. Smith, chief metallurgist of the Central Steel Company of Massillon, presented a paper entitled, "Manufacture and Uses of Alloy Steels." The members of the Philadelphia section of the A. S. M. E. were invited to attend this meeting.

PITTSBURGH CHAPTER

The Pittsburgh chapter of the Society held its regular March meeting on the evening of the 3rd in the Assembly Room of the Fort Pitt Hotel.

The U. S. Bureau of Mines motion pictures depicting the manufacture of a spark plug from the raw material to finished product and the heat treatment of automobile parts were shown. At the conclusion of the pictures, Duray Smith presided at a short business session. He then called upon W. H. Eisenman, national secretary of the Society, who had stopped over in Pittsburgh on Society business, to tell something of his recent trip to California. Mr. Eisenman recounted some interesting experiences and told of the splendid progress made by the Pacific Coast chapters. He also told of the efforts and hopes of the National Officers toward sustaining and even increasing the Society's service to its members.

Quite unexpectedly, J. Fletcher Harper of the Milwaukee chapter and a member of the board of directors of the Society, dropped in and he, too, was called upon to make a short address. He urgently requested all members to let the Recommended Practice Committee, of which Mr. Harper is

chairman, know their needs and to send in information which could be used for the data sheets, as the committee is trying to make the handbook the most complete and concise source of information possible.

The speaker of the evening, our National President, W. S. Bidle, was then welcomed and after a few remarks pertaining to the Society, he proceeded with his subject, "Heat Treatment Equipment." Mr. Bidle said he would describe the equipment which from his experience would answer the needs of a medium sized plant and which would give it facilities for handling a varied assortment of work. He first spoke of storage tanks for handling fuel oil and described a cement tank which he had found to be serviceable but, of course, could not be moved as could a steel one. When using oil for fuel he recommended having pumps and strainers in duplicate and for winter use, he had found 34°-36° Baume oil to be better on account of being easier to handle than the heavier and more viscuous fuel oils. He then described the compressor equipment, the burners—atomizers for oil and mixers for gas. He said that he had found gas fired furnaces to be better than oil fired ones for the lower drawing temperatures.

The various kinds of furnaces, which he said were the heat treaters' most important pieces of equipment, were then taken up. In order to equalize the pressure, he said he had found it advantageous to encircle the furnace with the blower pipe. Another recommendation was to have ample combustion area for oil fired furnaces. The furnace probably used would be an under-fired furnace and he especially cautioned the necessity for the proper support of the floor tiles to avoid their cracking under load. A lead bath and salt bath furnace was described which permitted their interchange. A barium chloride pot furnace for heating high speed steel had the drawback of suitable material for the pot which could withstand the necessary high temperature. Mr. Bidle was of the opinion that the rate of heating for the first 700-800 degrees Fahr. had a great deal to do with the warpage of high speed steel.

He then discussed quenching baths, recommending that duplicate pumps be installed in the circulating system for the oil, and he described several cooling systems.

In regard to the electric furnaces of various designs, he described many with their advantages.

In conclusion, he gave efficiency figures on the operation of the various types and kinds of furnaces, pointing out some errors in the computation of costs which were misleading.

The meeting was well attended and considerable interest was displayed in this subject. *H. A. Neeb, Jr.*

PROVIDENCE CHAPTER

A joint meeting of the Rhode Island chapter of the Society and the A. I. E. E., Power, Structural and Machine Shop sections of the Providence Engineering Society, was held in the auditorium of the Providence Gas

Company on Wednesday, February 25, at 8:00 p. m. The speaker, R. S. Wile, vice-president and consulting engineer of the Fabulosa Mines, Ltd., also consulting engineer with the Combustion Utilities Company of Toledo, Ohio, chose for his subject, "Gas Application and Fuel Costs." This was an illustrated lecture and dealt with the application of gas to the operations of annealing, hardening and forging, and presented some very interesting comparisons on the relative costs of operating with gas and other fuels.

The chapter held their March meeting on the 19th in the Rooms of the Providence Engineering Society at 8:00 p. m. W. M. Saunders, Saunders and Franklin, Providence, presented an illustrated paper entitled, "Cast Iron and Iron Castings." Mr. Saunders, who is known by foundry men all over the eastern part of the United States, has for 25 years been associated with many foundries as consulting metallurgist, and also has been active as a teacher of foundry chemistry. In his presentation, he traced the relationship between steel and cast iron, showing the effect of chemical and structural composition. He also described modern foundry practice, including the preparation of the sands, molds, cores, melting, pouring of metal, cleaning of castings, etc.

ROCHESTER CHAPTER

On March 9 the Rochester chapter of the Society, after entertaining the President and Secretary of the National Society, at an informal dinner, were in turn entertained by them, at the chapter's meeting, which was held at Mechanics' Institute.

Mr. Eisenman spoke on the past, present and future of the Society, bringing to light some very interesting incidents. His suggestion of compiling a history of the Society was enthusiastically received. Mr. Bidle then developed a commercial heat treating plant from the re-enforced concrete oil reservoir to the quenching bath. His discussion of the relative cost of electric, oil and gas heating was of decided value. No one who heard this talk, and there were about a hundred, could fail to profit by it. Moving pictures illustrating the heat treating methods used in the fabrication of the Hupp Motor Car preceded the talks. *F. T. Flaherty.*

SCHENECTADY CHAPTER

On Tuesday, March 24, the Schenectady chapter of the A. S. S. T. held a meeting in the Rose Room of the Twentieth Century restaurant. The speaker, Marcus A. Grossmann, metallurgist, United Alloy Steel Corp., Canton, Ohio, presented an illustrated paper entitled, "Manufacturing Problems in Alloy Steel."

SPRINGFIELD CHAPTER

On Tuesday, March 24, the Springfield chapter of the American Society for Steel Treating held a meeting in the Chamber of Commerce Building, at 8:00 p. m. A. H. Kingsbury, Crucible Steel Company of America, Atha Works, Harrison, N. J., gave a talk on "Tool Room Problems." Mr. Kingsbury, during his long association with the steel industry, has gained a very wide experience in solving tool problems and his presentation was very well received. The usual get-together dinner was served at the Highland Hotel at 6:30 p. m.

SYRACUSE CHAPTER

The Syracuse chapter of the A. S. S. T. held a meeting at the University Club on Monday, March 16, at which time, Major A. E. Bellis, of the Bellis Heat Treating Company, presented a paper on "Salt Bath Heating." Dinner was served at 6:30 p. m. preceding the meeting.

TORONTO CHAPTER

The Toronto chapter of the Society held meetings on February 13 and 27. On the former date, Professor O. W. Ellis continued his series of lectures on the Metallurgy of Iron and Steel. On the latter occasion the local chapter united with the local sections of the Engineering Institute of Canada and the American Society of Mechanical Engineers to hear Dr. Zay Jeffries speak on the subject of "More about Steel." Dr. Jeffries' address was greatly appreciated and gave rise to considerable discussion. A number of the members had the pleasure of hearing Dr. Jeffries on the following evening when he addressed the Royal Canadian Institute on the subject of "Hardness and Hardening."

The chapter held a meeting on March 13 in Room 32, Mining Building, at which time Prof. Ellis delivered the sixth lecture on the Metallurgy of Iron and Steel.

M. V. Willard.

TRI CITY CHAPTER

On Monday, March 16, the Tri City chapter of the A. S. S. T. held a joint meeting with the Quad-City Foundrymen's Association and the Tri City Section of the American Society of Mechanical Engineers in the LeClaire Hotel at 8:00 p. m. Major R. A. Bull, research director of the Electric Steel Foundries' Research Group, delivered an address on "Electric Steel Castings."

WORCESTER CHAPTER

At the March 26 meeting of the Worcester chapter of the Society, held at the Worcester Gas Light Company, A. C. Frey, works superintendent of this company, described the process of gas manufacture, after which a tour through the plant was made, where the actual making of gas was witnessed. Supper was served at 6:30 p. m. preceding the meeting.

ABSTRACTS OF TECHNICAL ARTICLES

(*Continued from Page 535*)

NOTE CAST COLUMNAR STRUCTURE. By R. J. Anderson, in *Foundry*, January 1, 1925, page 20.

This article points out that metal crystals grow along lines of heat flow in opposite directions, columnar crystallization being governed principally by the rate of solidification of the metal.

RESEARCH METHOD FOR BLAST FURNACES. By W. G. Imhoff and D. E. Ackerman, in *Iron Age*, January 15, 1925, page 203.

One difficult problem in conducting research investigations on the blast furnace is the great number of facts which have to be observed and recorded, due to the large scale on which the practical operations are carried. This article describes a method by the use of symbols to designate observed conditions, which greatly facilitates the work.

PROPERTIES OF HIGH RESISTANCE ALLOYS. By M. A. Hunter and A. Jones, Russell Sage Laboratory, Rensselaer Polytechnic Institute, in *Forging-Stamping-Heat Treating*, February, 1925, page 63.

The above was presented at the twenty-seventh annual meeting of the American Society for Testing Materials, Atlantic City, June, 1924, and gives a summary of the important physical constants of the well known high resistance alloys that are used for high temperatures.

IMPROVEMENTS IN HEAT TREATING EQUIPMENT. By Arthur L. Green, Buffalo Bolt Company, in *Forging-Stamping-Heat Treating*, March, 1925, page 84.

The author in this article tells how the heat treating facilities of this company are designed to assure accuracy and uniformity of product. Underground storage and cooling tanks are employed.

CONTROLLING GRAY IRON QUALITIES. By James Ward, in *Foundry*, March, 1925, page 186.

The author states that strength, grain and machinability of cast iron and semi-steel are determined largely by the elements contained and by the cooling rate. Good molding practice, proper design, suitable sand and correct cupola operation insure sound castings.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member; and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

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ACKER, J. A., (M-3), superintendent, forge department, Bourne Fuller Co.; *mail* 10906 Pasadena Ave., Cleveland.

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Items of Interest

THE organization of some form of a national standardizing body in each of the American Republics was one of the formal proposals of the first official Pan American Conference on standardization recently held in Lima, Peru, according to a report to the American Engineering Standards Committee by Mr. Albert W. Whitney, who served as chairman of the U. S. Government delegation.

Mr. Whitney reported that standardization is not yet developed in any of the Latin American countries on an organized basis, and it was the belief of the conference that the subject would play an important part in the future of these countries, first, in making more efficient and expediting their industrial organization, second, in simplifying and clarifying international trade and third, and most important, the development of better methods of producing and marketing their products.

The recommendation of the conference, which was an official body representing thirteen countries, were made to the Inter-American High Commission and to the twenty-one American Republics represented on it.

The report states that,

"The Pan American Conference on standardization, held at Lima, Peru, December 23rd to January 6th, to which I had the honor of being not only your representative, but a delegate of the U. S. Government, was an occasion of great significance. The conference was held coincidently with the Pan American Scientific Congress and immediately following the centario celebration of Peruvian independence. Thirteen American Republics sent officially accredited representatives as follows: Brazil, Costa Rica, Cuba, Guatemala, Haiti, Mexico, Nicaragua, Panama, Paraguay, Peru, United States, Uruguay, Venezuela.

"The subject of standardization was received with great interest, and there was a general recognition of the important part that it could play in the future development of the Latin American States. Standardization can be used in these countries in three ways, first in expediting and making more efficient their own industrial development, second in improving the effectiveness of their buying, and, third and most important in the development of better methods for producing and marketing their own raw products. The way in which Oregon secured a market in the East for its apples was essentially a feat of standardization. There are opportunities in the Latin States which can be taken advantage of only by similar methods.

"The tangible and formal results of the conference were the signing of a set of resolutions by the duly accredited representatives which provided for the development and promotion of standardization work by the various countries, and for the development of such work on an international basis. The relation of such work and its development on an international basis was

entrusted to the Inter-American High Commission. Provision was made for holding the next conference, either two or three years hence, in the United States.

"It is believed that the Lima Conference and the work of the Inter-American High Commission will be effective in bringing about a very considerable degree of standardization work among the Latin American States at once.

"In connection with the work of the conference, I conferred with the President of Peru, who stated that he was convinced of the great importance of the work and that a Bureau of Standards would be started by the Peruvian Government at once."

The other official delegates from the United States were Dr. Guillermo A. Sherwell, Secretary of the Inter-American High Commission, and Morris H. Bletz, Department of Commerce; and unofficial American delegates attending the conference were: American Society of Mechanical Engineers, Eng. J. H. Cerscede; The Society of Automotive Engineers, Kirke K. Hoagg; National Committee of Commercial Engineers of the Bureau of Education, Dr. Glen Levin Swiggett.

The following is an abstract of the Final Act of the conference:

First: It is recommended that the American countries enter into a convention containing the following essential points:

(a) An agreement to provide for continuous study and to secure the establishment of common standards and nomenclature, uniform quality bases, simplified classifications, and standard specifications for raw materials and industrial products.

(b) To carry out this agreement the several countries will bind themselves to establish within their respective jurisdictions, one or more organizations, which may be under the administration of the government or under private administration, or under administration composed of both governmental and private elements, as may seem best to each of the states signatories of the convention.

(c) The organization or organizations which may be established in each country will constitute national centers for the investigation and study of theories relating to this subject; they will establish methods of test, will be charged with the custody of accepted standards, and will either serve as intermediary itself or will maintain a close contact with the national organization serving as intermediary for the international exchange of ideas and experiences in this field.

(d) The aforesaid organization, whether governmental, private, or mixed, should comply with certain prescriptions and regulations, including the following:

1—The maintenance of an adequate personnel.

2—Measures to obtain adequate cooperation and to consult representatives of all interests and enterprises in their country, in the establishment of national standards.

3—The obligations of publishing or having published the methods of

procedure followed, the results obtained, and any other information which may be of interest.

(e) In order to maintain inter-American communication in this subject and to secure the establishment of inter-American Standards, the Inter-American High Commission, through the National Section of each country and the Central Executive Council, is charged with the receiving and distributing of information relating to the work done in each country; the Commission will direct or perform such studies as it may believe advisable, will draw up proposals, and will take all necessary measures within its sphere of action to promote the establishment of inter-American standards.

(f) The nations will bind themselves to increase the technical and other personnel of their respective sections of the Inter-American High Commission, if this be necessary, in order that no economic obstacles may be encountered in this work.

Second: It is recommended that the Inter-American High Commission study and draft the convention referred to in the previous resolution, redrafting it in such form as may be most suitable to realize speedily the aims of these resolutions.

Third: Until the foregoing convention has been drafted and signed by the nations of America, it is recommended that the Inter-American High Commission work for the adoption within each country of measures in accordance with the proposed convention.

Fourth: It is recommended that the Inter-American High Commission undertake the gradual compilation of a vocabulary or list of standard scientific terms, in Spanish, Portuguese, English and French, and that all nations make such arrangements as may be necessary to cooperate in this work.

Fifth: In connection with the uniformity of weights and measures it is recommended:

(a) That this subject be entrusted to a committee for study and report at the next conference. The Inter-American High Commission is charged with the appointment of this Commission, upon which all American countries should be necessarily represented.

(b) That the units of weights and measures used in the various countries tend toward the metric system and that the new specifications, and any modifications which may be made in those now in existence, be expressed in C. G. S. units.

(c) That in catalogues and industrial and technical literature, where weights and measures of other systems are used, these should be accompanied so far as possible by their equivalents in the metric decimal system.

Sixth: It is recommended that there be held a Second Pan American Conference on the Uniformity of Specifications within a period of not more than three years, in the United States of America, and in the city and at the time which the Inter-American High Commission may designate.

Seventh: Let the Central Executive Council be informed of the recommendations approved at this conference, which are set forth in the appendix to these resolutions, in order that it may procure their adoption in the countries of America; let also be sent to the Council a copy of the proceedings

of this conference in order that it may draw from them the proposals which it may be proper to present to the American countries. Pending the publication of the minutes of the First Pan American Conference on the Uniformity of Specifications, the Council is authorized to publish, in whole or in part, the proceedings to which reference has been made.

Eighth: Let these resolutions be communicated to all the governments of America with the request that they give thereto their approval and support. Let them also be communicated to the National Sections of the Inter-American High Commission, to the Central Executive Council of said Commission, and to the Pan American Union, for such purposes as may be proper.

W. W. Sanderson, general sales manager of the Carborundum Company, Niagara Falls, N. Y., announces the appointment of Farrand P. Hall as district sales manager in charge of the carborundum sales organization and branch warehouse at Cleveland. Mr. Hall succeeds John MacArthur, who has been district sales manager at Cleveland during the past five years. Mr. MacArthur has been assigned to special sales service work and will be located at the main office of the Carborundum Company at Niagara Falls. The appointments were effective April 1, 1925.

Mr. Hall joined the Carborundum sales force in 1914 as salesman covering the territory in and about Montreal and the Maritime Provinces. From 1916 to 1922 he was engaged in the retail hardware business and returned to the Carborundum Company in 1922.

Mr. MacArthur has been a member of the Carborundum Sales force since 1909, having been appointed to the sales staff of the Boston branch warehouse of the company in February of that year. In January, 1919, he was made district sales manager at Cleveland.

Arthur L. Cramp, formerly with the Diamond Chain Company of Indianapolis, has accepted a position with the Fort Wayne, Indiana, plant of the International Harvester Company, as assistant chief inspector.

A. S. Taylor, formerly sales engineer for the United Alloy Steel Corp., Canton, Ohio, is now with the Central Steel Company of Massillon, Ohio, in the same capacity.

W. F. Scully, formerly president of the Advance Furnace and Engineering Company of Springfield, Mass., has rejoined the organization of the Gilbert and Barker Manufacturing Company as manager of furnace and factory sales. Mr. Scully was with the Gilbert and Barker Manufacturing Company from 1910 to 1920, leaving in the latter year to organize the Advance Furnace and Engineering Company. The patents, patterns, records, etc., of the Advance Company have been purchased by the Gilbert and Barker Manufacturing Company, who will be in a position to supply repair parts for Advance Company equipment.

Leeds and Northrup Company of Philadelphia have recently published bulletins No. 533 entitled, "The Burrows Permeameter—the Epstein Core

Loss Apparatus,'' and No. 984—''The Vreeland Oscillator—and Other Devices for Producing High Frequency Alternating Current.''

Carborundum has long been recognized as one of the greatest of all abrasives or grinding materials and now it has become a necessity in the radio world in the form of the new Carborundum detector unit for reflex and crystal sets.

The carborundum detector unit is of the cartridge type and is made with carborundum specially manufactured and tested for radio use exclusively.

The carborundum detector unit is fixed and permanent. No adjustments are necessary. There is no need for searching for a sensitive spot because this detector remains sensitive indefinitely and will not burn out.

Exhaustive tests have proved that the carborundum detector unit will make possible a sharper tuning, the reception of clear true tones, greater selectivity and greater volume and distance on any properly constructed reflex or crystal set. Many radio enthusiasts have also found that this detector can be used in place of detector tube and with splendid results.

The carborundum detector unit is laboratory-tested and it is sold by radio dealers and supply houses with the guarantee of the Carborundum Company back of it. More complete information regarding this new carborundum product can be had by writing to the Carborundum Company, Niagara Falls, N. Y.

Some statistical genius once figured that it was costing him $210.00 a year to wind the various clock-driven contrivances in his plant. When he started to check up on how much it cost him when somebody forgot to wind them—he issued a rush order to replace every clock-mechanism with electric drive wherever possible.

Doubtless figuring along these lines has been going on generally, for today the demand is overwhelmingly for the electric-driven clock mechanisms. The instrument manufacturers themselves are unquestionably responsible for this far-reaching efficiency.

For quite some time recording instruments—pyrometers, thermometers, resistance thermometers, pressure gages, tachometers and CO_2 meters—have been supplied with a synchronous motor clock, where alternating current is available. Where only direct current is used, the instruments are usually operated off an impulse time clock system—such as is used in most industrial plants.

The Roessler and Hasslacher Chemical Company of New York City make the interesting announcement that they are now producing TRI-CHLORETHYLENE and TETRA-CHLORETHANE. The manufacture of these materials is an entirely new development in this country, although this company has been importing them for several years. The value of these commodities in the metal industry has been definitely established, as they possess the inestimable advantage of being non-inflammable.

The United States Civil Service Commission announces the following open competitive examinations for the positions of assistant scientific aid, minor laboratory apprentice and junior physicist.

These examinations are for the purpose of filling vacancies in the U. S. Bureau of Standards. The salary for the first position is $1500 per year and that for the second position $900 per year and that for the third position $1860 per year.

Receipt of applications will close April 25, 1925.

Full information and application blanks may be obtained from the United States Civil Service Commission, Washington, D. C., or the secretary of the board of U. S. civil-service examiners at the post office or customhouse in any city.

Continuing a research program instituted several years ago, the cooperative mining courses of the Carnegie Institute of Technology are offering four fellowships in coal mining research for the college year of 1925-1926 in cooperation with the Pittsburgh Experiment Station of the U. S. Bureau of Mines and an advisory board of mine operators and engineers. The fellowships, according to the announcement, are open to graduates of colleges, universities and technical schools.

Each fellowship carries a stipend of $750, paid in ten installments. The purpose of the fellowships, it is announced, is to help solve problems in mining and utilization of fuels which are of special importance to the bituminous coal industry.

Although the subjects for investigation next year have not yet been finally selected by the advisory board, the following suggested topics are being considered in formulating the final list, it is announced:

1. Origin and constitution of coal: (a) Correlation of coal seams by microscopic characteristics; (b) The determination and separation of the coking constituents of coal; (c) Comparison of methods of determining the oil and tar yields of coal.

2. Acid mine waters: (a) Action of acid mine water on concrete and protective coatings; (b) Prevention of stream pollution by acid mine water.

3. Coal mining: (a) Study of efficiency in blasting coal; (b) Efficiency of mechanical devices in coal mining; (c) Friction losses and efficiency in mine ventlation; (d) Friction losses in mine cars.

4. Coal washing: (a) Wet and dry methods; (b) Utilization and disposal of washery waste.

5. Utilization of coal: (a) Combustion of low volatile bituminous coal in house heating furnaces; (b) Investigation of methods for sampling and analysis of pulverized coal; (c) Study of physical properties of coke in relation to domestic heating; (d) Correlation of laboratory fusing temperature tests with clinker formation of various coals.

6. Mine safety: (a) Study of methods of collecting dust samples in mines; (b) Study of effect of fineness and nature of material on its efficiency for rock dusting coal mines; (c) Study of electrical methods for detecting

(*Continued on Page 34 Adv. Sec.*)

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

ETALLURGIST—Young man, well educated, with years experience in chemical and metallurgical ork (control and research) in large steel plant sires permanent situation where chance of adancement will be offered. Will gladly consider conection that would eventually lead to position of sales presentative. Details on request. Address 4-1.

SSISTANT METALLURGIST desires position. Age college graduate, with 2¾ years' experience research work, ferrous and non-ferrous. At esent employed and can give excellent references. cation unimportant. Address 3-5.

ETALLURGIST, CHEMIST with 14 years' experice in the metallography, heat-treating, physical sting and manufacture of the non-ferrous alloys, sires position. Experience also embraces the rrous industry of steels, alloy steels, and the rro-alloys and compounds of vanadium, tungsten d molybdenum. Address 3-10.

HEMIST AND METALLURGICAL ENGINEER ith 6 years' practical experience in mill, factory, boratory and executive capacity, desires to make new connection. Age 29. Address 3-15.

SSISTANT METALLURGIST desires position. 10 ars' practical experience in heat-treating departent and laboratory of several well known concerns. ston district preferred. Married. Address 3-10.

ETALLURGIST, CHEMIST with 12 years' experice in chemical, physical, microscopical laboratory ork, as well as heat treating, forging and melting, sires position. Qualified to take charge. Cleveand district preferred. Address 3-35.

NDUSTRIAL POSITION is desired by assistant proessor of metallurgy and metallography in leading outhern University. 33 years of age. Married. S. degree in chemistry with major work in metalgraphy. Experienced in microphotography and pyometry. Has theoretical training necessary for the aking of a good practical man. Always willing to ork. Address 4-30.

UPERINTENDENT of wire drawing desires posiion with opportunity for advancement. Six years' perience as superintendent of cold drawing plant, andling all grades and shapes of steel. Two years' perience in metallurgical laboratory and heat treatg department. Address 4-20.

SSISTANT TO PRODUCTION MANAGER, SUPERNTENDENT OR ENGINEER OF TESTS, desires osition. 38 years of age, 15 years' experience on oduction and in laboratories of large steel plants, undries and auto manufacture. Graduate chemist, etallurgist, metallographist and heat treater. Also a Salle University training in accountancy and cost counting. Address 4-25.

POSITIONS OPEN

SALES ENGINEER WANTED. If you are looking for an opportunity for rapid advancement and an excellent chance to assume worth while responsibility, with compensation according to your sales ability, describe your experiences fully so an appointment can be made for personal interview. You must have had sales and engineering experience, and should know something about instruments, gauges, and CO_2 recorders. Address 3-20.

PYROMETER SERVICE ENGINEER WANTED with experience in maintenance and repairing of pyrometers. Prefer men with at least 3 years' technical experience, having had some experience in a pyrometer manufacturing plant. Give full details as to experience in first letter. Will be required to travel about half time. Address 3-25.

WANTED RECENT GRADUATE OF METALLURGY for metallography laboratory; modern laboratory and equipment. Salary $125.00 per month. Please include references and training in first letter. Location Pittsburgh. Address 3-40.

FOR SALE: One Eaton electric drawing furnace complete with automatic control panel and thermometer. Guaranteed to be in A-1 condition. All new elements. Cost $1,000.00 new, will sell at 50c on the dollar and guarantee. Address Claud S. Gordon Co., 708 West Madison Street, Chicago.

WANTED young man for steel and non-ferrous analytical work with some knowledge of steel and its heat treatment. Buffalo and Rochester district. Address 4-5.

WANTED THOROUGHLY EXPERIENCED HARDENER FOREMAN—Must have executive experience and complete knowledge of the heat treatment of high speed, carbon, alloy steels and carbonizing. Hardening plant is constructed with all modern appliances. State age, experience and salary expected. Address 4-10.

WANTED RECENT GRADUATE IN METALLURGY for work in metallography under a specialist, in Eastern plant. If applicant is located in East, will arrange for personal interview. Address 4-15.

FOR SALE

FOR SALE—50-ton Tinius Olsen Pull Testing Machine. Countershaft Drive, 1917 Model, Serial 4586. Very reasonable. Address Bay State Machinery Company, South Boston, Mass.

methane in mine air; (d) Study of effect of pressure and temperature on products of combustion of mining explosives.

7. Spontaneous combustion: (a) Survey of relative tendency of various coals to fire spontaneously; (b) Determination of the constituents of a coal seam which are responsible for gob fires.

8. Mine explosions: (a) Time-pressure relations in dust explosions; (b) Conductivity and specific heat of coal; (c) Modification of Stokes' law for settling of coal dust particles; (d) Effect of electric field in propagation of explosions.

The period of appointment to the fellowships begins August 17, 1925. According to the announcement, applications should be sent to the Supervisor of Cooperative Mining Courses and are due not later than May 1, 1925.

A fellowship in metallurgy of $1500 has just been established at the University of Wisconsin by the Milwaukee Steel Foundry Co., Milwaukee. Leo Shapiro of Madison has been appointed under the fellowship to make a study of the technical problems peculiar to the steel casting industry. He is carrying on the research projects at the university in collaboration with A. T. Baumer, works manager of the Milwaukee foundry, who is enrolled as a graduate student in the university class of graduate engineers conducted in Milwaukee by the University of Wisconsin extension division. Mr. Baumer's experiments are furthered by Mr. Shapiro in the engineering laboratory at Madison. "Wisconsin ranks first among the states, per unit of population, in the number of steel foundries and the number of electric steel foundries within its boundaries," said Prof. E. R. Shorey, of the department of metallurgy, in announcing the work of the Milwaukee concern.

F. J. Ryan & Co., Philadelphia, has appointed the Stanley P. Rockwell Co., Hartford, Conn., and the Alfred H. Bullion Co., San Francisco, as territorial representatives for the sale of its standard heating equipment, including electric furnaces, oil burners, automatic temperature and combustion control apparatus and other industrial heating specialties.

Dr. George W. Sargent has been elected chairman of directors of the Molybdenum Corporation of America, Pittsburgh. He has been the president of the company since its organization. J. W. Weitzenkorn, formerly vice-president and general manager, will succeed Dr. Sargent as president.

Glen Riegel, for several years metallurgical engineer for the Gerlinger Electric Steel Casting Co., West Allis, Milwaukee, has been appointed works manager. Albert M. Weis, foreman of electric furnaces, has been appointed foundry superintendent.

Prof. Kotaro Honda and R. Yamanda have measured the amount of wear under different frictional horsepower and under different coefficients of fric-

(*Continued on Page 36 Adv. Sec.*)

S. M. Co. Brinell Machine

This machine applies a pressure of 3,000 Kilos to a 10 mm. ball and gives results in Brinell numerals, the international standard for indicating hardness of metals.

The Pressure is applied quickly and evenly, and a patented feature prevents the leakage of the hydraulic fluid.

Pieces from $\frac{3}{16}$ inch to 12 inches may be accommodated. The anvil is adjustable to irregular shaped pieces.

The Standard Machine Adopted by

American Can Co.
American Machine & Mfg. Co.
E. C. Atkins & Co.
Canadian Fairbanks Morse Co.
Carbon Steel Co.
Carnegie Steel Co.
Chicago Pneumatic Tool Co.
Columbia Steel & Shafting Co.
Curtiss Aeroplane & Motor Co.
Dayton Engineering Laboratories
Dominion Steel & Foundry Co., Ltd.
Eagle Pitcher Lead Co.
Firth-Sterling Steel Co.
Henry Ford & Son, Inc.
General Electric Co.
Hughes Tool Co.
Latrobe Electric Steel Co.
Lincoln Motor Co.
Maxwell Motor Co.
McMyler Interstate Co.
Nash Motors Co.
Oliver Chilled Plow Works
Parish & Pool Co.
Piston Ring Co.
Pittsburgh Testing Laboratory
Pollak Steel Co.
Premier Motor Corp.
Railway Steel Spring Co.
Standard Foundry Co
Standard Steel Car Co.
Standard Steel Spring Co.
Studebaker Corp.
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Union Switch & Signal Co.
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And Many Others

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"Everything for the Laboratory"
PITTSBURGH, PA.

tion with respect to soft metals (copper, cadmium, magnesium, tin, antimony, zinc and bismuth), also carbon steels. They find that in these metals the amount of wear is proportional to the frictional horsepower, provided that the coefficient of friction is constant. The amount of wear of these metals and steels under a constant frictional horsepower increases with the coefficient of friction. The effect of the velocity of abrasion on the amount of wear is negligibly small.

Robert M. Kirk has resigned his position as western sales manager with the Hardite Metals Co., Inc., of New York, and beginning April 6 entered the employ of the General Alloys Company, manufacturers of Q-Alloys, as special factory representative. Mr. Kirk, while comparatively a new-comer in the A. S. S. T. ranks, having engaged in the sale of alloys only about two years, is a veteran electrical and mechanical engineer, having served in various capacities with the Westinghouse Electric and Mfg. Co. for twenty-three years, and as general manager of an international paint manufacturing concern for three years. Mr. Kirk acquired many friends and several customers in the steel treating field, who will be glad to hear of his advancement. For the next few months his activities will cover principally the middle western field, where he will co-operate with the various Q-Alloy representatives to aid in further developing the engineering service extended by the General Alloys Company to their customers.

In co-operation with the Bureau of Mines and the State Mining Experiment Station, the School of Mines and Metallurgy of the University of Missouri, offers four fellowships. These fellowships are open to graduates who have the equivalent of a Bachelor of Science degree and have had the proper training in mining, metallurgy or chemistry, and who are qualified to undertake research work. The income of each followship is $800 per annum for the twelve months beginning July 1, 1925. Fellows pay fees amounting to approximately $30.00 per year.

Fellows will register as students in the School of Mines and Metallurgy of the University of Missouri, and become candidates for the degree of Master of Science (unless this or an equivalent degree has been earned.) Their class work will be directed by the heads of the departments of instruction, but the greater portion of their time will be spent in research work under the direction of the Bureau of Mines staff resident at the School of Mines. The purpose of this work is to undertake the solution of definite problems confronting the mining and metallurgical industries of the State of Missouri. For 1925-26, the four fellowships will be granted in the following subjects: Metallurgy of Zinc, Refractories for Metallurgy for Zinc, Physical Metallurgy (heat treatment of steel.) Applications, with a certified copy of collegiate record, statement of professional experience, and names and addresses of three references will be received up to June 15, 1925. The application should be addressed to the Director, School of Mines and Metallurgy, University of Missouri, Rolla, Mo.

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